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**(54) Use of a catalyst in epoxy compositions**

Verwendung eines Katalysators für Epoxyharz-Zusammensetzungen

Utilisation d'un catalyseur pour des résines époxy

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**EP-A- 0 066 543 EP-A- 0 239 784  
WO-A-86/00627 DE-B- 2 412 882  
GB-A- 2 099 825 US-A- 4 366 295  
US-A- 4 775 734**

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## Description

The present invention concerns the use of latent catalysts in epoxy resin compositions containing epoxycontaining compounds, and aromatic hydroxyl-containing compounds and a solvent.

Epoxy resins have been precatalyzed with phosphonium and other compounds to provide latent compositions which form advanced, higher molecular weight epoxy resins when admixed with an aromatic hydroxyl-containing compound as disclosed by Perry in U.S. Patent 3,948,855 and Canadian Patent 893,191; by Dante et al. in U.S. Patent 3,477,990; by Mueller et al. in U.S. Patent 3,547,881; by Tyler, Jr. et al. in U.S. Patent 4,366,295; and by Cragar in Canadian Patent 858,648.

While compositions containing these catalysts and an epoxy resin are somewhat stable, such compositions which also contain an aromatic hydroxyl-containing compound are lacking in stability.

Curable compositions containing epoxy resins and aromatic hydroxyl-containing compounds and a catalyst therefor would be highly desirable in the preparation of storage stable coatings, storage stable electrical encapsulants, storage stable formulations for preparing mechanical and electrical laminates and composites, storage stable one package molding compositions, storage stable curable compositions for use in resin transfer molding (RTM) and reaction injection molding (RIM) applications and the like.

From DE-A-24 12 882 a solid, storage-stable composition comprising an epoxy resin having at least two vicinal epoxy groups per molecule and a phenol novolac resin having at least two hydroxy groups per molecule and a curing promoter containing tetraphenylborate is known.

In EP-A-239 784 a curable composition containing a polyepoxide and a halogenated bisphenol and optionally a solvent is disclosed which can be cured by heating in the presence of a catalyst such as imidazoles. Tetrahaloborate-onium compounds are mentioned as alternative catalyst but no reference is made to storage stability of said compositions.

WO-A-86/00627 describes a solid curable composition comprising an epoxy resin, an extender compound, a curing agent, a stabilizer and a 35 % solution of tetrabutylphosphonium acetate-acetic acid complex in methanol containing a stoichiometric amount of fluoroboric acid. This composition was stored but a stabilizing effect of the tetrafluoroborate is not disclosed.

Thus the object of the present invention is to impart storage stability to solvent-based epoxy resin compositions containing aromatic hydroxyl-containing compounds.

This object is solved by the use of at least one catalyst (C) resulting from contacting

(1) at least one compound selected from

- (a) an onium compound of the element nitrogen, phosphorus, sulfur or arsenic,
- (b) an amine compound or an acid adduct thereof, with

(2) at least one compound selected from

- (a) an inorganic acid free of boron or a metal salt thereof, said inorganic acid having a weak nucleophilic anion,
- (b) an inorganic acid containing boron or a metal salt thereof, said inorganic acid being represented by the formula  $\text{HBR}_3\text{R}'$  wherein each R is independently hydrogen or an aliphatic, cycloaliphatic or aromatic hydrocarbyl group having from 1 to 12 carbon atoms or a halogen and R' is a hydrocarbonoxy, a hydrocarbonamino, a hydrocarbonphosphino or a halogen atom and
- (c) any combination of components (a) or (b);

whereby components (C-1) and (C-2) are contacted in quantities which satisfy following viscosity requirement: if 181.5 g of a diglycidyl ether of bisphenol A having an epoxy equivalent weight of 181.5 and 114 g of bisphenol A are heated in 73.88 g monomethylether of propylene glycol monoacetate (PMA) under a nitrogen atmosphere between 80°C - 100°C until homogeneous and cooled to ambient temperature and 9 mmol of catalyst (C) are added that mixture has a viscosity measured at 25°C of 75% or less than the viscosity of a like composition except that the catalyst consists only of component (C-1) said viscosity being determined after storage for 14 days at 50°C

in a precatalyzed resin formulation further comprising:

- (A) at least one compound containing an average of more than one epoxide group per molecule and
- (B) at least one compound containing an average of more than one aromatic hydroxyl group per molecule other than an alkenylphenol polymer, in a quantity to provide a ratio of 0.05 to 20 aromatic hydroxyl groups per epoxide group and

(D) a solvent in a quantity of 0.05 to 100 mmol per epoxide equivalent in component (A) to impart storage stability to said precatalyzed resin formulation, wherein storage stability is defined in that said precatalyzed resin formulation is capable of being stored at 50°C for at least 14 days.

The acid adducts used in the present invention preferably have a relatively strong-nucleophilic anion. The acid adducts are reacted with the metal salts of the inorganic acids. The term weak-nucleophilic as employed herein means that the material has a nucleophilicity value "n" from zero to less than 2.5 as described by C. G. Swain and C. B. Scott in J. Am. Chem. Soc., Vol. 75, p. 141 (1953). The term relatively strong-nucleophilic as employed herein means that the material has a nucleophilicity value "n" of 2.5 or greater as described by C. G. Swain and C. B. Scott in J. Am. Chem. Soc., Vol. 75, p. 141 (1953).

#### Preparation of the Catalysts

The catalysts employed in the present invention are prepared by simply mixing in the desired proportions and stirring to insure intimate contact the onium, amine or nitrogen-containing compound with the acid or salt of an acid having a weak-nucleophilic anion and which acid or acid salt is free of any organic substituent. The contact can be conducted at temperatures of from 0°C to 100°C, preferably from 20°C to 60°C for a time sufficient to complete any reaction which occurs. The time depends upon the temperature, but usually from 1 to 120, preferably from 5 to 60 minutes is sufficient.

The components from which the catalysts are prepared are mixed in proportions which provide from 0.6 to 1.4, suitably from 0.75 to 1.12, more suitably from 0.85 to 1.35, most suitably from 0.93 to 1.1 moles of acid per mole of onium, amine or heterocyclic nitrogen-containing compound. The preferred ratios depend upon which onium, amine or heterocyclic amine compound is mixed with the acid or acid salt. For example, the preferred ratio of moles of acid or acid salt per mole of imidazole compound is from 0.85:1 to 1.12:1 while the most preferred ratio is in the range of from 0.93:1 to 1.1:1. For phosphonium compounds, the preferred ratio is from 0.95:1 to 1.35:1, more preferably from 1.1:1 to 1.25:1 moles of acid per mole of phosphonium compound. For other catalysts, it is easy to determine the optimum ratios of acid or acid salt to onium, amine or heterocyclic amine compound by mixing the components together in various ratios and conducting simple, routine experiments such as those described in Examples 1-9, 18-26 and 39-45. When the amount of acid or acid salt is less than 0.6 mole per mole of imidazole the catalyst is less latent and begins to approach the reactivity of the original imidazole prior to reaction with the acid or acid salt. When the amount of acid or acid salt is more than 1.4 moles per mole of phosphonium, the catalyst becomes less latent to the point that at a ratio of 1.5:1 the catalyst becomes an accelerator as compared to the original onium-containing compound prior to reaction with the acid. When the amount of acid or acid salt is more than 1.14 moles per mole of imidazole, the catalyst becomes less latent to the point that at a ratio of 1.17:1 the catalyst becomes an accelerator as compared to the original imidazole compound prior to reaction with the acid or acid salt.

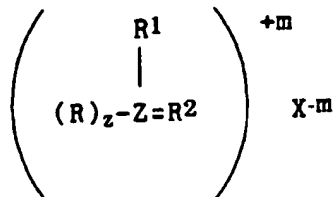
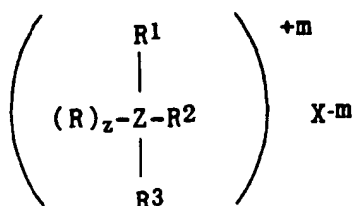
The catalyst is employed in a quantity from 0.05 to 100, suitably from 0.1 to 50, more suitably from 0.1 to 30, more suitably from 0.5 to 20, most suitably from 1 to 10 millimoles of catalyst per epoxide equivalent.

#### Catalytic Components

Suitable onium compounds which can be employed herein include, ammonium, phosphonium, sulfonium and arsonium compounds. Particularly suitable such compounds include, those represented by the following formulas IA or IB

Formula IA.

Formula IB.



wherein each R, R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> is independently a hydrocarbyl group having from 1 to 18, preferably from 1 to 9, carbon

atoms, or a hydrocarbonyl group having from 1 to 18, preferably from 1 to 9, carbon atoms which group also contains one or more oxygen, sulfur, halogen, or nitrogen atoms or two of such R, R<sup>1</sup>, R<sup>2</sup> and R<sup>3</sup> groups can combine to form a heterocyclic ring containing one or more atoms other than carbon atoms; each X is the anion portion of an acid of a relatively strong nucleophilic acid; Z is phosphorus, nitrogen, sulfur or arsenic; m has a value equal to the valence of the anion X; and z has a value of zero or 1 depending on the valence of Z. Particularly suitable onium or amine compounds which can be reacted or complexed with the inorganic acids having a weak-nucleophilic anion to form the catalysts of the present invention include, for example, ethyltriphenyl phosphonium acetate, ethyltriphenyl phosphonium acetate-acetic acid complex, tetrabutyl phosphonium acetate, tetrabutyl phosphonium acetate-acetic acid complex, ethyltriphenyl phosphonium chloride, ethyl triphenyl phosphonium iodide, tetrabutyl phosphonium chloride, tetrabutyl phosphonium iodide, tetrabutylphosphonium hydroxide, tetrabutylammonium hydroxide, tetraethylammonium hydroxide, tetramethylammonium hydroxide, N-methylmorpholine, 2-methylimidazole, triethylamine, N,N,N',N'-tetramethylethylenediamine, ethyltri(2-hydroxyethyl)-ammonium hydroxide, ethyltri(2-ethoxyethyl)ammonium hydroxide, triethyl(2-thioethylethyl)ammonium hydroxide, N-methyl-N-methylenemethanaminium acetate, N-methyl-N-methylenemethanaminium acetate-acetic acid complex, N-methyl-N-methylenemethanaminium chloride, N-methyl-N-methylenemethanaminium iodide, N-methylpyridinium acetate, N-methylpyridinium acetate-acetic acid complex, N-methylpyridinium chloride, N-methylpyridinium iodide, 1-ethyl-2,3-dimethylimidazolium acetate, 1-ethyl-2,3-dimethylimidazolium acetate-acetic acid complex, 1-ethyl-2,3-dimethylimidazolium chloride, 1-ethyl-2,3-dimethylimidazolium iodide, N-methylquinolinium acetate, N-methylquinolinium acetate-acetic acid complex, N-methylquinolinium chloride, N-methylquinolinium iodide, N-methyl-1,3,5-triazinium acetate, N-methyl-1,3,5-triazinium acetate-acetic acid complex, N-methyl-1,3,5-triazinium chloride, N-methyl-1,3,5-triazinium iodide, and combinations thereof.

Suitable relatively strong-nucleophilic acid anions include, for example, carboxylates, halides, phosphates, phosphites, carbonates, bicarbonates, hydroxide, cyanide, thiol, sulfate, and thiosulfate. Particularly suitable such nucleophilic acid anions include, for example, acetate, acetate-acetic acid complex, propionate, chloride, and iodide.

Particularly suitable onium or amine-acid complexes which can be reacted with the salt of inorganic acids having a weak-nucleophilic anion to form the catalysts employed in the present invention include, for example tetrabutylphosphonium chloride, tetrabutylammonium chloride, tetraethylammonium chloride, tetramethylammonium chloride, triethylamine hydrochloride, 2-methylimidazole hydrochloride, N-methylmorpholine hydrochloride, ethyltri(2-hydroxyethyl)ammonium chloride, triethyl(2-thioethylethyl)ammonium chloride, and mixtures thereof.

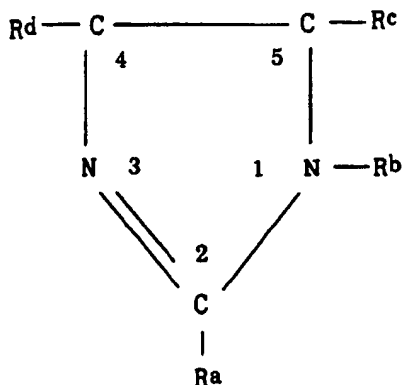
The non-heterocyclic amine compounds which can be suitably employed herein include, for example, primary, secondary, tertiary, aliphatic, cycloaliphatic or aromatic amines.

Suitable non-heterocyclic amines which can be employed herein include those containing suitably from 1 to 60, more suitably from 2 to 27, most suitably from 2 to 18, carbon atoms. Particularly suitable such amines include, for example, ethylamine, diethylamine, triethylamine, n-propylamine, di-n-propylamine, tri-n-propylamine, isopropylamine, diisopropylamine, triisopropylamine, butylamine, dibutylamine, tributylamine, methyldibutylamine, and combinations thereof.

Suitable heterocyclic nitrogen-containing compounds which can be employed herein include, for example, imidazoles, imidazolidines, imidazolines, oxazoles, pyrroles, thiazoles, pyridines, pyrazines, morpholines, pyridazines, pyrimidines, pyrrolidines, pyrazoles, quinoxalines, quinazolines, phthalazines, quinolines, purines, indazoles, indoles, indolazines, phenazines, phenarsazines, phenothiazines, pyrrolines, indolines, piperidines, piperazines, and combinations thereof.

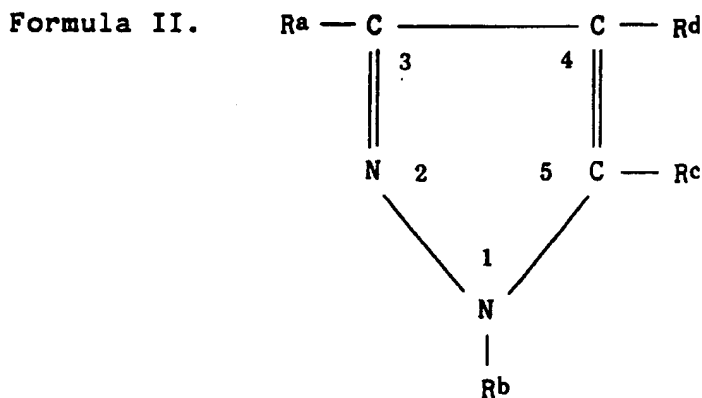
Suitable imidazole compounds which can be employed herein include, for example, those represented by the following formula I

Formula I.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup> and R<sup>d</sup> is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 2 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur or halogen or the like substituent, or R<sup>b</sup> and R<sup>c</sup> can combine to form a 5 or 6 membered ring with the carbon and nitrogen atoms from the imidazole ring to which they are attached or R<sup>c</sup> and R<sup>d</sup> can combine to form a 5 or 6 membered ring with the two carbon atoms from the imidazole ring to which they are attached. Particularly suitable imidazole compounds include, for example, 2-methylimidazole, 2-ethylimidazole, 2-propylimidazole, 2-butylimidazole, 2-pentylimidazole, 2-hexylimidazole, 2-cyclohexylimidazole, 2-phenylimidazole, 2-nonylimidazole, 2-undecylimidazole, 2-heptadecylimidazole, 2-ethyl-4-methylimidazole, 2-phenyl-4-methylimidazole, 1-benzylimidazole, 1-ethyl-2-methylbenzimidazole, 2-methyl-5,6-benzimidazole, 1-vinylimidazole, 1-allyl-2-methylimidazole, 2-cyanoimidazole, 2-chloroimidazole, 2-bromoimidazole, and combinations thereof. Suitable imidazoles wherein one or more of the R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, or R<sup>d</sup> group contain oxygen, sulfur or halogen or the like substituents include, for example, 1-(2-hydroxypropyl)-2-methylimidazole, 2-phenyl-4,5-dimethylimidazole, 2-phenyl-4-methyl-5-hydroxymethylimidazole, 2-chloromethylbenzimidazole, 2-hydroxybenzimidazole, and any combination thereof. Most particularly suitable are 2-methylimidazole, 2-ethyl-4-methylimidazole, 1,2-dimethylimidazole and 2-phenylimidazole.

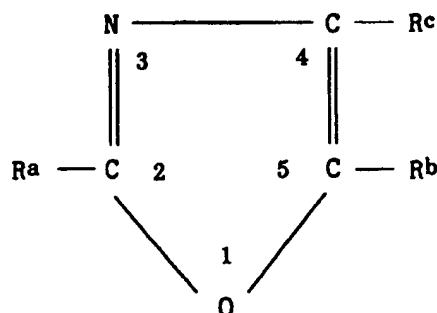
Suitable pyrazole compounds which can be employed herein include, for example, those represented by the following formula II



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup> and R<sup>d</sup> is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent, or R<sup>b</sup> and R<sup>c</sup> can combine to form a 5 or 6 membered ring with the carbon and nitrogen atoms from the pyrazole ring to which they are attached or R<sup>c</sup> and R<sup>d</sup> can combine to form a 5 or 6 membered ring with the two carbon atoms from the pyrazole ring to which they are attached. Particularly suitable pyrazole compounds include, for example, pyrazole, 1-methylpyrazole, 3-methylpyrazole, 4-butylpyrazole, 1-methyl-3-propylpyrazole, 3-ethyl-5-methylpyrazole, 1-(3-hydroxypropyl)pyrazole, 5-phenylpyrazole, 5-benzylpyrazole, 1-phenyl-3-methylpyrazole, 1-cyanopyrazole, 3-chloropyrazole, 4-bromo-1-methylpyrazole, and any combination thereof.

Suitable oxazole compounds which can be employed herein include, for example, those represented by the following formula III

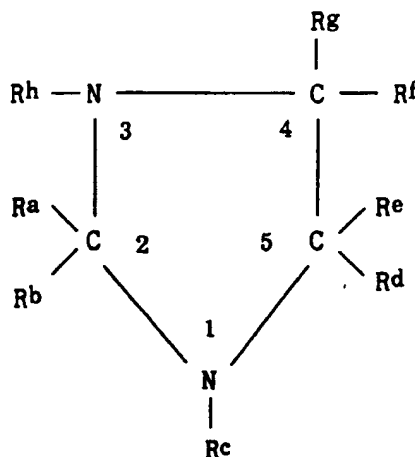
Formula III.



wherein each  $R^a$ ,  $R^b$ , and  $R^c$  is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable oxazole compounds include, for example, oxazole, 4-methyloxazole, 2-methyloxazole, 4-butyloxazole, 2-methyl-5-propyloxazole, 2-ethyl-4-methyloxazole, 2-(3-hydroxypropyl)oxazole, 4-phenyloxazole, 5-benzyloxazole, 2-phenyl-5-methyloxazole, 2-cyanooxazole, 4-chlorooxazole, 4-bromo-2-methyloxazole, and any combination thereof.

Suitable imidazolidine compounds which can be employed herein include, for example, those represented by the following formula IV

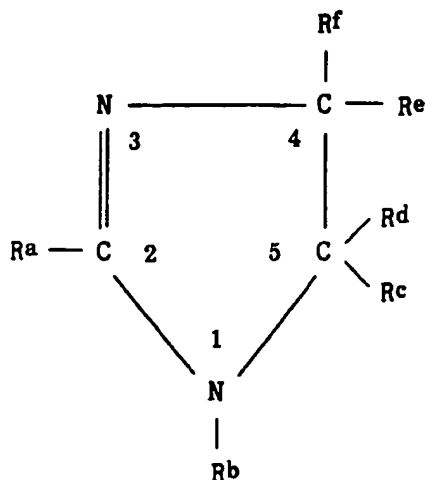
Formula IV.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$  and  $R^h$  is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable imidazolidine compounds include, for example, imidazolidine, 1-methylimidazolidine, 2-methylimidazolidine, 4-butyrimidazolidine, 1-methyl-3-propylimidazolidine, 1-ethyl-4-methyl-imidazolidine, 1-(3-hydroxypropyl)imidazolidine, 2-phenylimidazolidine, 1-benzyimidazolidine, 2-phenyl-1-methylimidazolidine, 4-cyanoimidazolidine, 4-chloroimidazolidine, 4-bromo-1-methylimidazolidine, and any combination thereof.

Suitable imidazoline compounds which can be employed herein include, for example, those represented by the following formula V

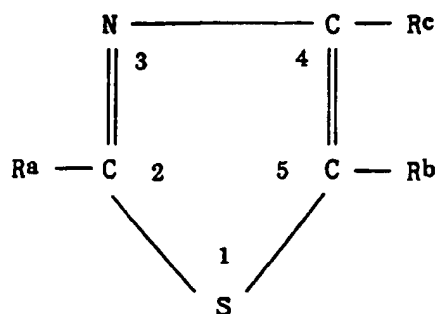
**Formula V.**



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup> and R<sup>f</sup> is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable imidazoline compounds include, for example, imidazoline, 1-methylimidazolidine, 2-methylimidazolidine, 4-butylimidazolidine, 1-methyl-2-propylimidazolidine, 1-ethyl-4-methylimidazolidine, 1-(3-hydroxypropyl)imidazolidine, 2-phenylimidazolidine, 1-benzylimidazolidine, 2-phenyl-1-methylimidazolidine, 4-cyanoimidazolidine, 5-chloroimidazolidine, 5-bromo-1-methylimidazolidine, and any combination thereof.

Suitable thiazole compounds which can be employed herein include, for example, those represented by the following formula VI

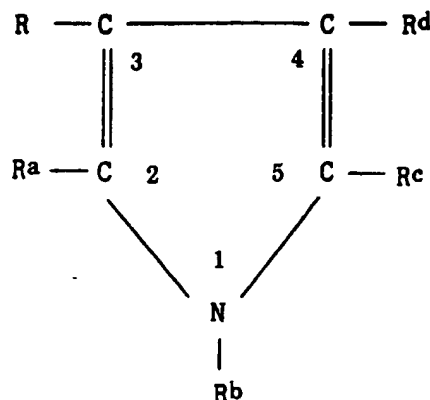
Formula VI.



wherein each R<sup>a</sup>, R<sup>b</sup>, and R<sup>c</sup> is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable thiazole compounds include, for example, thiazole, 2-methylthiazole, 5-methylthiazole, 4-butylthiazole, 2-methyl-4-propylthiazole, 4-ethyl-5-methylthiazole, 2-(3-hydroxypropyl)thiazole, 2-phenylthiazole, 2-benzylthiazole, 4-phenyl-5-methylthiazole, 2-cyanothiazole, 5-chlorothiazole, 5-bromo-2-methylthiazole, and any combination thereof.

Suitable pyrrole compounds which can be employed herein include, for example, those represented by the following formula VII

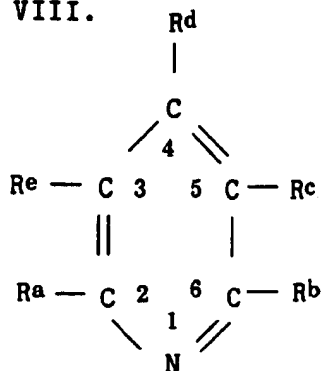
Formula VII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$  and  $R^e$  is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable pyrrole compounds include, for example, pyrrole, 1-methylpyrrole, 2-methylpyrrole, 3-butylpyrrole, 1-methyl-2-propylpyrrole, 2-ethyl-3-methylpyrrole, 1-(3-hydroxypropyl)pyrrole, 2-phenylpyrrole, 1-benzylpyrrole, 2-phenyl-1-methylpyrrole, 3-cyanopyrrole, 3-chloropyrrole, 2-bromo-1-methylpyrrole, and any combination thereof.

Suitable pyridine compounds which can be employed herein include, for example, those represented by the following formula VIII

Formula VIII.

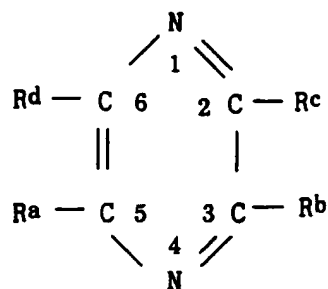


wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$  and  $R^e$  is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable pyridine compounds include, for example, pyridine, 2-methylpyridine, 3-methylpyridine, 4-butylpyridine, 2-methyl-3-propylpyridine, 3-ethyl-4-methylpyridine, 4-(3-hydroxypropyl)pyridine, 2-phenylpyridine, 3-benzylpyridine, 4-phenyl-2-methylpyridine, 3-cyanopyridine, 2-chloropyridine, 3-bromo-5-methylpyridine, and any combination thereof.

Suitable pyrazine compounds which can be employed herein include, for example, those represented by the following formula IX



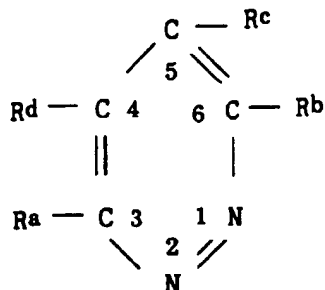
Formula IX.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup> and R<sup>d</sup> is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable pyrazine compounds include, for example, pyrazine, 2-methylpyrazine, 3-methylpyrazine, 2-butylpyrazine, 2-methyl-5-propylpyrazine, 2-ethyl-6-methylpyrazine, 2-(3-hydroxypropyl)pyrazine, 2-phenylpyrazine, 2-benzylpyrazine, 2-phenyl-3-methylpyrazine, 2-cyanopyrazine, 2-chloropyrazine, 2-bromo-5-methylpyrazine, and any combination thereof.

Suitable pyridazine compounds which can be employed herein include, for example, those represented by the following formula X

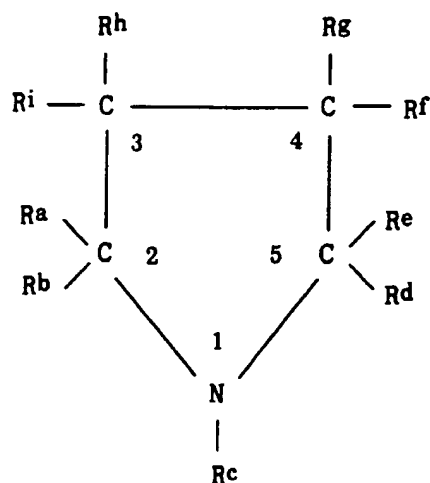
Formula X.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, and R<sup>d</sup> is independently hydrogen, halogen, cyano or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable pyridazine compounds include, for example, pyridazine, 3-methylpyridazine, 4-methylpyridazine, 3-butylpyridazine, 3-methyl-4-propylpyridazine, 3-ethyl-6-methylpyridazine, 4-(3-hydroxypropyl)-pyridazine, 3-phenylpyridazine, 4-benzylpyridazine, 4-phenyl-5-methylpyridazine, 4-cyanopyridazine, 4-chloropyridazine, 3-bromo-5-methylpyridazine, and any combination thereof.

Suitable pyrrolidine compounds which can be employed herein include, for example, those represented by the following formula XI

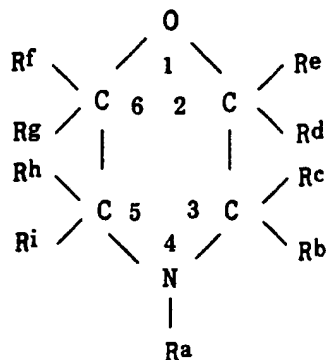
Formula XI.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$  and  $R^i$  is independently hydrogen, halogen, cyano or a hydrocarbyl group having from 1 to 18 carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable compounds include, for example, pyrrolidine, 1-methyl-pyrrolidine, 4-phenylpyrrolidine, 2-methylpyrrolidine, 3-methylpyrrolidine, 1-butylpyrrolidine, 1-methyl-2-propylpyrrolidine, 3-ethyl-4-methylpyrrolidine, 2-(3-hydroxypropyl)-pyrrolidine, 1-phenyl-2-methyl-pyrrolidine, 2-cyanopyrrolidine, 2-chloropyrrolidine, 2-bromo-1-methylpyrrolidine, and any combination thereof.

Suitable morpholine compounds which can be employed herein include, for example, those represented by the following formula XII

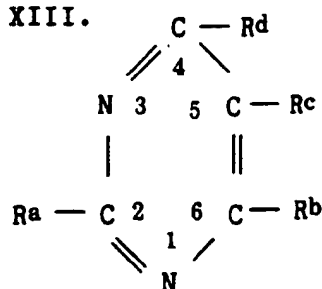
Formula XII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$  and  $R^i$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 2 to 9, carbon atoms or such hydrocarbyl group containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable morpholine compounds include, for example, morpholine, 4-methylmorpholine, 3-methylmorpholine, 4-butyl-morpholine, 4-methyl-3-propylmorpholine, 2-ethyl-3-methylmorpholine, 4-(3-hydroxypropyl)-morpholine, 2-phenylmorpholine, 4-benzylmorpholine, 3-phenyl-1-methylmorpholine, 3-cyanomorpholine, 3-chloromorpholine, 3-bromo-4-methylmorpholine, and any combination thereof.

Suitable pyrimidine compounds which can be employed herein include, for example, those represented by the following formula XIII

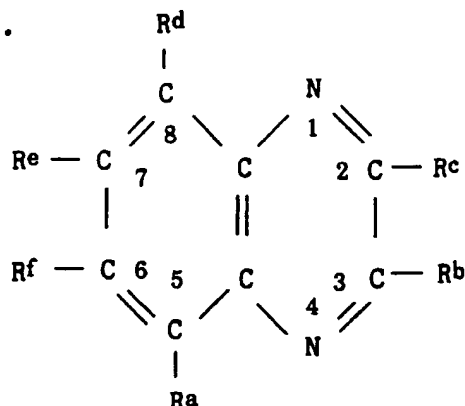
Formula XIII.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup> and R<sup>d</sup> is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable pyrimidine compounds which can be employed herein include, for example, pyrimidine, 2-methylpyrimidine, 4-methylpyrimidine, 2-butylpyrimidine, 2-methyl-4-propylpyrimidine, 4-ethyl-5-methylpyrimidine, 2-(3-hydroxypropyl)pyrimidine, 2-phenylpyrimidine, 2-benzylpyrimidine, 4-phenyl-2-methylpyrimidine, 4-cyanopyrimidine, 2-chloropyrimidine, 4-bromo-2-methylpyrimidine, and any combination thereof.

Suitable quinoxaline compounds which can be employed herein include, for example, those represented by the following formula XIV

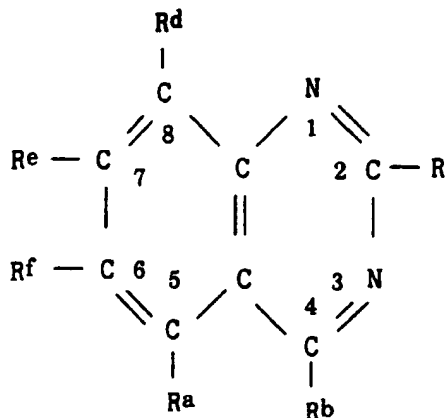
Formula XIV.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, and R<sup>f</sup> is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable quinoxaline compounds include, for example, quinoxaline, 2-methylquinoxaline, 5-methylquinoxaline, 2-butylquinoxaline, 2-methyl-3-propylquinoxaline, 5-ethyl-6-methylquinoxaline, 2-(3-hydroxypropyl)quinoxaline, 2-phenylquinoxaline, 5-benzylquinoxaline, 2-phenyl-5-methylquinoxaline, 2-cyanquinoxaline, 2-chloroquinoxaline, 2-bromo-5-methylquinoxaline, and any combination thereof.

Suitable quinazoline compounds which can be employed herein include, for example, those represented by the following formula XV

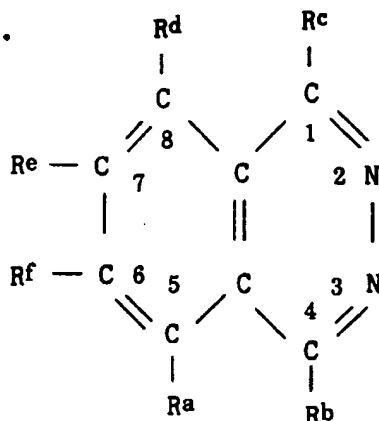
Formula XV.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ , and  $R^f$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable quinazoline compounds include, for example, quinazoline, 2-methylquinazoline, 4-methylquinazoline, 2-butylquinazoline, 2-methyl-4-propylquinazoline, 5-ethyl-6-methylquinazoline, 2-(3-hydroxypropyl)quinazoline, 2-phenylquinazoline, 2-benzylquinazoline, 2-phenyl-4-methylquinazoline, 4-cyanoquinazoline, 4-chloroquinazoline, 2-bromo-4-methylquinazoline, and any combination thereof.

Suitable phthalazine compounds which can be employed herein include, for example, those represented by the following formula XVI

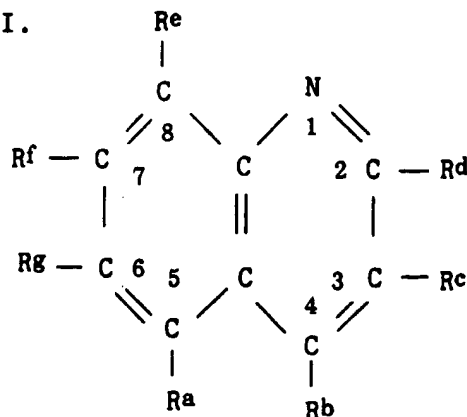
Formula XVI.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ , and  $R^f$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable phthalazine compounds include, for example, phthalazine, 1-methylphthalazine, 6-methylphthalazine, 1-butylphthalazine, 1-methyl-4-propylphthalazine, 1-ethyl-6-methylphthalazine, 1-(3-hydroxypropyl)-phthalazine, 5-phenylphthalazine, 1-benzylphthalazine, 1-phenyl-4-methylphthalazine, 1-cyanophthalazine, 1-chlorophthalazine, 1-bromo-4-methylphthalazine, and any combination thereof.

Suitable quinoline compounds which can be employed herein include, for example, those represented by the following formula XVII

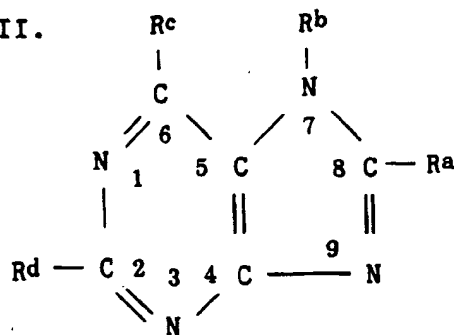
Formula XVII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$  and  $R^g$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable quinoline compounds which can be employed herein include, for example, quinoline, 2-methylquinoline, 3-methylquinoline, 4-butylquinoline, 5-methyl-2-propylquinoline, 2-ethyl-3-methylquinoline, 3-(3-hydroxypropyl)quinoline, 3-phenylquinoline, 4-benzylquinoline, 3-phenyl-2-methylquinoline, 3-cyanoquinoline, 4-chloroquinoline, 2-bromo-3-methylquinoline, and any combination thereof.

Suitable purine compounds which can be employed herein include, for example, those represented by the following formula XVIII

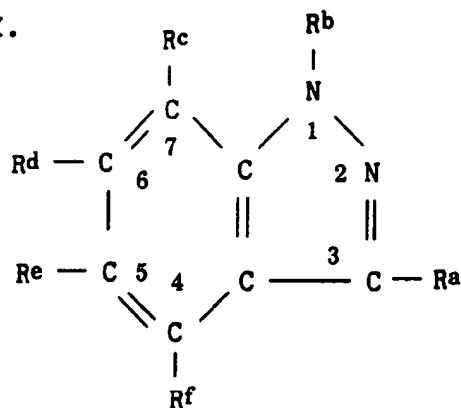
Formula XVIII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$  and  $R^d$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable purine compounds include, for example, purine, 2-methylpurine, 8-methylpurine, 6-butylpurine, 2-methyl-8-propylpurine, 6-ethyl-8-methylpurine, 8-(3-hydroxypropyl)purine, 2-phenylpurine, 2-benzylpurine, 6-phenyl-2-methylpurine, 8-cyanopurine, 2-chloropurine, 8-bromo-2-methylpurine, and any combination thereof.

Suitable indazole compounds which can be employed herein include, for example, those represented by the following formula XIX

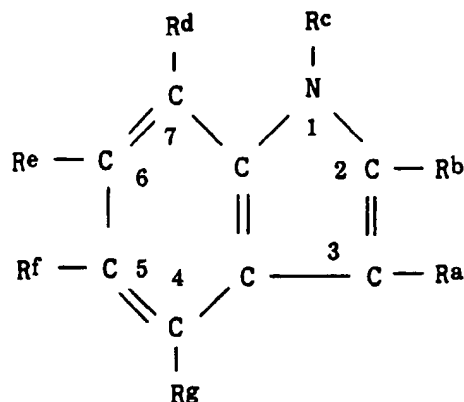
Formula XIX.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup> and R<sup>f</sup> is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable indazole compounds include, for example, indazole, 1-methylindazole, 3-methylindazole, 1-butylindazole, 1-methyl-3-propylindazole, 1-ethyl-5-methylindazole, 3-(3-hydroxypropyl)indazole, 3-phenylindazole, 6-benzylindazole, 6-phenyl-1-methylindazole, 3-cyanoindazole, 5-chloroindazole, 3-bromo-1-methylindazole, and any combination thereof.

Suitable indole compounds which can be employed herein include, for example, those represented by the following formula XX

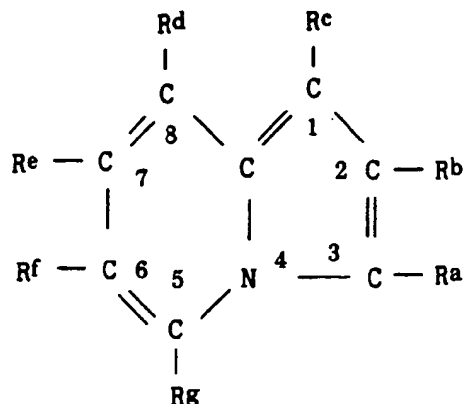
Formula XX.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup> and R<sup>g</sup> is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable indole compounds which can be employed herein include, for example, indole, 1-methylindole, 2-methylindole, 3-butylindole, 1-methyl-2-propylindole, 2-ethyl-3-methylindole, 1-(3-hydroxypropyl)indole, 2-phenylindole, 1-benzylindole, 2-phenyl-1-methylindole, 2-cyanoindole, 5-chloroindole, 3-bromo-1-methylindole, and any combination thereof.

Suitable indolizine compounds which can be employed herein include, for example, those represented by the following formula XXI

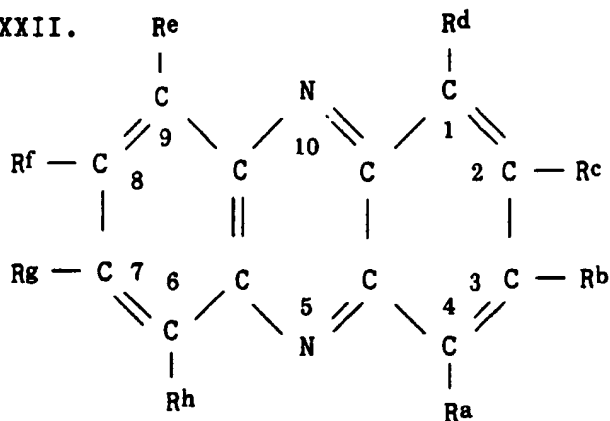
Formula XXI.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$  and  $R^g$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable indolizine compounds include, for example, indolizine, 1-methylindolizine, 2-methylindolizine, 3-butylindolizine, 5-methyl-1-propylindolizine, 2-ethyl-1-methylindolizine, 6-(3-hydroxypropyl)indolizine, 3-phenylindolizine, 7-benzylindolizine, 2-phenyl-3-methylindolizine, 5-cyanoindolizine, 7-chloroindolizine, 3-bromo-5-methylindolizine, and any combination thereof.

Suitable phenazine compounds which can be employed herein include, for example, those represented by the following formula XXII

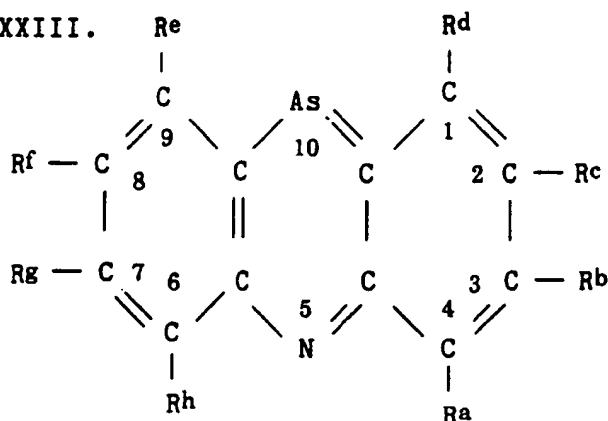
Formula XXII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$  and  $R^h$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable phenazine compounds which can be employed herein include, for example, phenazine, 1-methylphenazine, 2-methylphenazine, 2-butylphenazine, 1-methyl-7-propylphenazine, 1-ethyl-4-methylphenazine, 2-(3-hydroxypropyl)phenazine, 1-phenylphenazine, 1-benzylphenazine, 1-phenyl-7-methylphenazine, 2-cyanophenazine, 1-chlorophenazine, 1-bromo-2-methylphenazine, and any combination thereof.

Suitable phenarsazine compounds which can be employed herein include, for example, those represented by the following formula XXIII

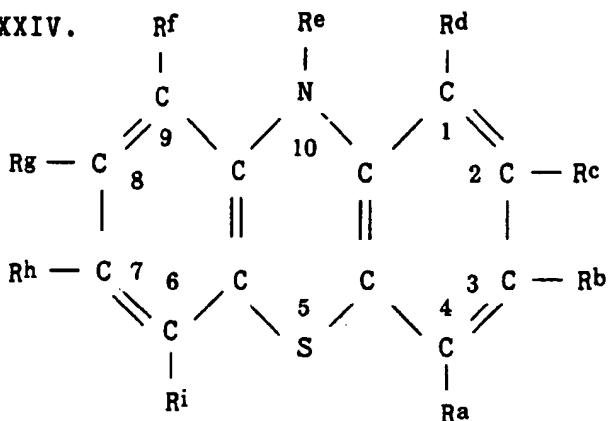
Formula XXIII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$  and  $R^h$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable phenarsazine compounds which can be employed herein include, for example, phenarsazine, 1-methylphenarsazine, 2-methylphenarsazine, 4-butylphenarsazine, 1-methyl-6-propylphenarsazine, 2-ethyl-3-methylphenarsazine, 1-(3-hydroxypropyl)-phenarsazine, 4-phenylphenarsazine, 3-benzylphenarsazine, 2-phenyl-7-methylphenarsazine, 3-cyanophenarsazine, 1-chlorophenarsazine, 1-bromo-8-methylphenarsazine, and any combination thereof.

Suitable phenothiazine compounds which can be employed herein include, for example, those represented by the following formula XXIV

Formula XXIV.

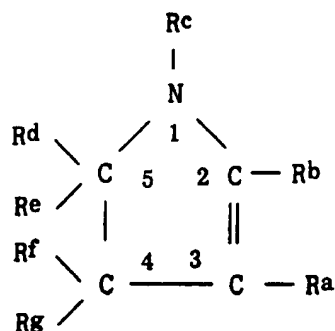


wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$  and  $R^i$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable phenothiazine compounds include, for example, phenothiazine, 10-methylphenothiazine, 1-methylphenothiazine, 2-butylphenothiazine, 10-methyl-4-propylphenothiazine, 2-ethyl-3-methylphenothiazine, 4-(3-hydroxypropyl)phenothiazine, 10-phenylphenothiazine, 1-benzylphenothiazine, 10-phenyl-4-methylphenothiazine, 7-cyanophenothiazine, 4-chlorophenothiazine, 4-bromo-10-methylphenothiazine, and any combination thereof.

Suitable pyrrole compounds which can be employed herein include, for example, those represented by the following formula XXV



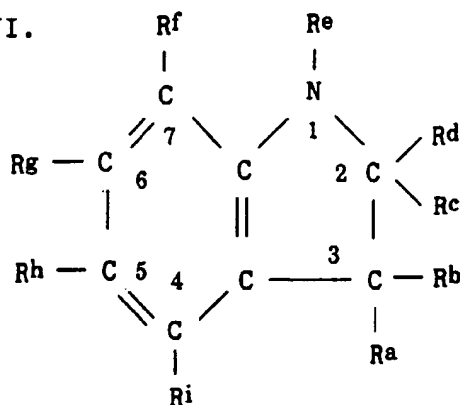
Formula XXV.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$  and  $R^g$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable pyrrolidine compounds include, for example, pyrrolidine, 2-methylpyrrolidine, 4-methylpyrrolidine, 5-butylpyrrolidine, 5-methyl-1-propylpyrrolidine, 1-ethyl-3-methylpyrrolidine, 1-(3-hydroxypropyl)pyrrolidine, 5-phenylpyrrolidine, 1-benzylpyrrolidine, 1-phenyl-4-methylpyrrolidine, 3-cyanopyrrolidine, 5-chloropyrrolidine, 2-bromo-1-methylpyrrolidine, and any combination thereof.

Suitable indoline compounds which can be employed herein include, for example, those represented by the following formula XXVI

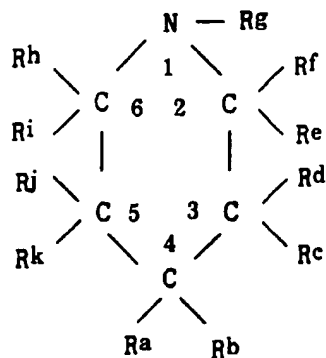
Formula XXVI.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$  and  $R^i$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable indoline compounds include, for example, indoline, 1-methylindoline, 2-methylindoline, 3-butylindoline, 1-methyl-2-propylindoline, 2-ethyl-2-methylindoline, 1-(3-hydroxypropyl)indoline, 1-phenylindoline, 1-benzylindoline, 1-phenyl-2-methylindoline, 5-cyanoindoline, 7-chloroindoline, 5-bromo-1-methylindoline, and any combination thereof.

Suitable piperidine compounds which can be employed herein include, for example, those represented by the following formula XXVII

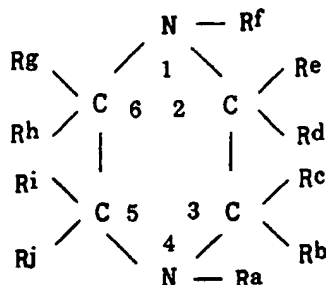
## Formula XXVII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$ ,  $R^i$ ,  $R^j$  and  $R^k$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Suitable piperidine compounds which can be employed herein include, for example, piperidine, 1-methylpiperidine, 2-methylpiperidine, 3-butylpiperidine, 1-methyl-2-propylpiperidine, 2-ethyl-4-methylpiperidine, 1-(3-hydroxypropyl)-piperidine, 1-phenylpiperidine, 1-benzylpiperidine, 1-phenyl-2-methylpiperidine, 4-cyanopiperidine, 3-chloropiperidine, 4-bromo-1-methylpiperidine, and any combination thereof.

Suitable piperazine compounds which can be employed herein include, for example, those represented by the following formula XXVIII

## Formula XXVIII.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$ ,  $R^i$  and  $R^j$  is independently hydrogen, or a hydrocarbyl group having suitably from 1 to 18, more suitably from 1 to 9, carbon atoms or such hydrocarbyl groups containing an oxygen, sulfur, cyano or halogen or the like substituent. Particularly suitable piperazine compounds which can be employed herein include, for example, piperazine, 1-methylpiperazine, 2-methylpiperazine, 3-butylpiperazine, 1-methyl-4-propylpiperazine, 1-ethyl-3-methylpiperazine, 1-(3-hydroxypropyl)-piperazine, 2-phenylpiperazine, 1-benzylpiperazine, 1-methyl-3-phenylpiperazine, 2-cyanopiperazine, 2-chloropiperazine, 1,4-dimethyl-2-bromopiperazine, and any combination thereof.

Suitable boron containing acids include, for example, those represented by the formula  $BR_3R'$  wherein each R is independently hydrogen or an aliphatic, cycloaliphatic or aromatic hydrocarbon group having suitably from 1 to 12, more suitably from 1 to 6, most suitably from 1 to 4, carbon atoms or a halogen; and  $R'$  is a group hydrocarbonoxy, hydrocarbonamino, a hydrocarbonphosphino, or a halogen atom, particularly fluorine, chlorine or bromine. The term hydrocarbon means any aliphatic, cycloaliphatic, aromatic, aryl substituted aliphatic, alkyl substituted aromatic groups.

Fluoboric acid is sometimes referred to as fluoroboric acid or hydrogen tetrafluoroborate. Any of these expressions refer to the chemical represented by the formula  $HBF_4$ .

Suitable such acids containing boron include, for example, hydrogen fluorotriphenylborate, hydrogen chlorotriphenylborate, hydrogen fluorotributylborate, hydrogen phenyltrifluoroborate. Most particularly suitable such acid is fluoboric acid.

The term hydrocarbonoxy means that a hydrocarbyl group as previously defined has an oxygen atom between it and the boron atom. Likewise, the term hydrocarbonamino and hydrocarbonphosphino mean that there is an amine or phosphine group between the hydrocarbyl group and the boron atom.

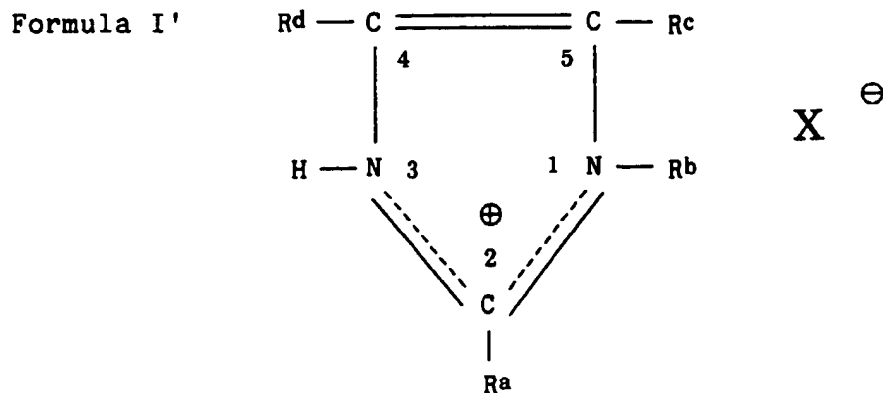
Particularly suitable inorganic acids which are free of boron, said acid having a weak nucleophilic anion include, for example, fluoarsenic acid, fluoantimonic acid, fluophosphoric acid, chloroarsenic acid, chloroantimonic acid, chlo-

rophosphoric acid, perchloric acid, chloric acid, bromic acid, iodic acid, and any combination thereof.

Suitable metal salts of inorganic acids free from any organic substituents and having a weak nucleophilic anion include, for example, salts of those metals of Groups I and II of the Periodic Table of the Elements published by Sargent-Welch Scientific Company as catalog number S-18806. Particularly such salts include, for example, the sodium, potassium, lithium, calcium, barium, magnesium and silver salts of such inorganic acids.

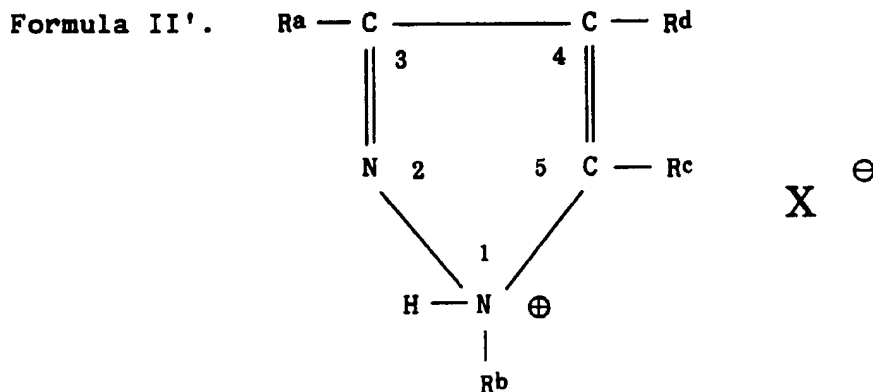
#### Examples of the Catalysts

The following compounds are examples of the catalysts of the present invention. Imidazolonium compounds represented by the following formula I'



wherein  $R^a$ ,  $R^b$ ,  $R^c$  and  $R^d$  are previously defined in Formula I and X is the anion portion of (a) an inorganic acid free of boron having a weak nucleophilic anion or (b) a boron containing inorganic acid represented by the formula  $HBR_3R'$  wherein each R is independently hydrogen or an aliphatic, cycloaliphatic or aromatic hydrocarbyl group having from 1 to 12 carbon atoms or a halogen and  $R'$  is a halogen.

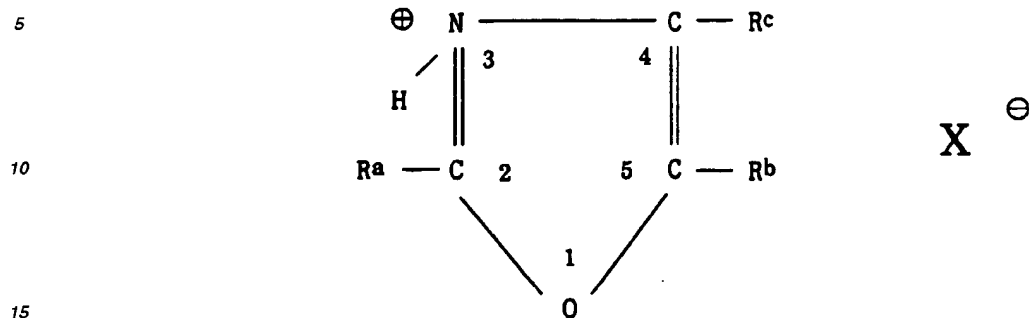
Pyrazolinonium compounds represented by the following formula II'



wherein each  $R^a$ ,  $R^b$ ,  $R^c$  and  $R^d$  is previously defined in Formula II; and X is the anion portion of an acid having a weak-nucleophilic anion.

Oxazolinonium compounds represented by the following formula III'

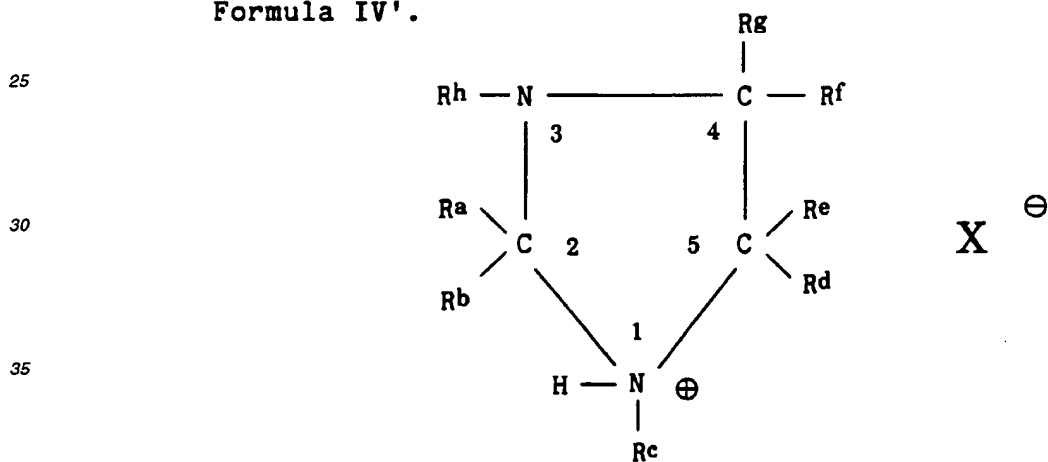
Formula III'.



wherein each  $R^a$ ,  $R^b$  and  $R^c$  is previously defined in Formula III; and  $X$  is the anion portion of an acid having a weak-nucleophilic anion.

20 Imidazolidinonium compounds represented by the following formula IV'

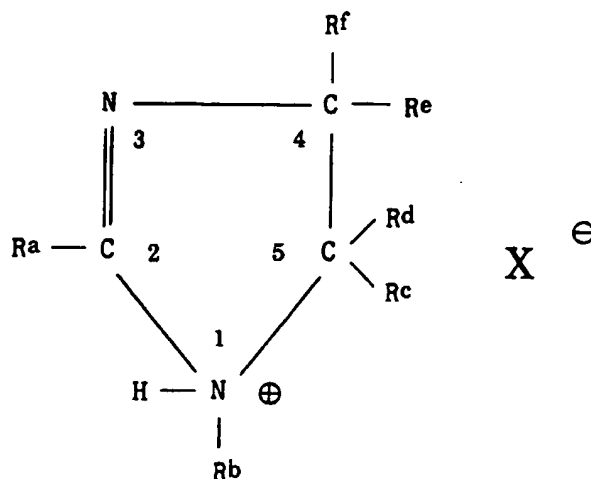
Formula IV'.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$  and  $R^h$  is previously defined in Formula IV; and  $X$  is the anion portion of an acid having a weak-nucleophilic anion.

Imidazolinonium compounds represented by the following formula V'

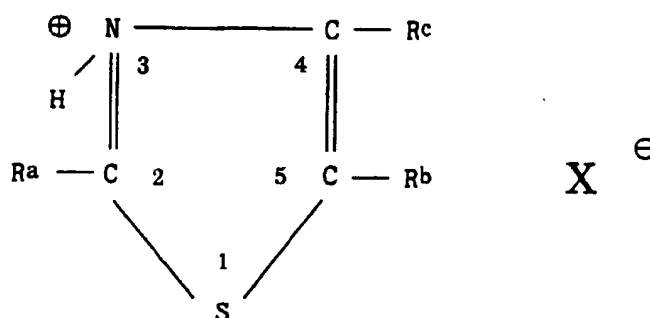
Formula V'.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$  and  $R^f$  is previously defined in Formula V; and X is the anion portion of an acid having a weak nucleophilic anion.

Thiazolonium compounds represented by the following formula VI'

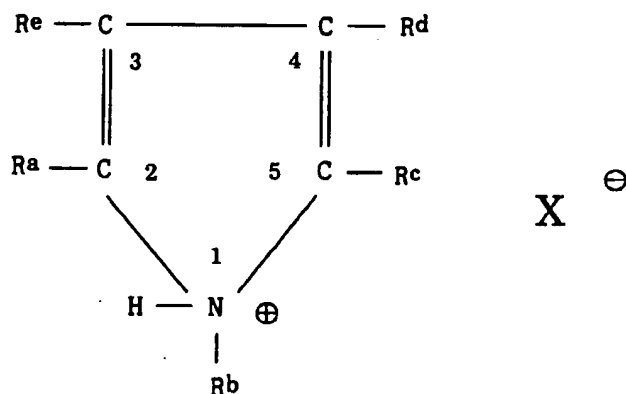
Formula VI'.



wherein each  $R^a$ ,  $R^b$  and  $R^c$  is previously defined in Formula VI; and X is the anion portion of an acid having a weak nucleophilic anion.

Pyrrolonium compounds represented by the following formula VII'

Formula VII'.

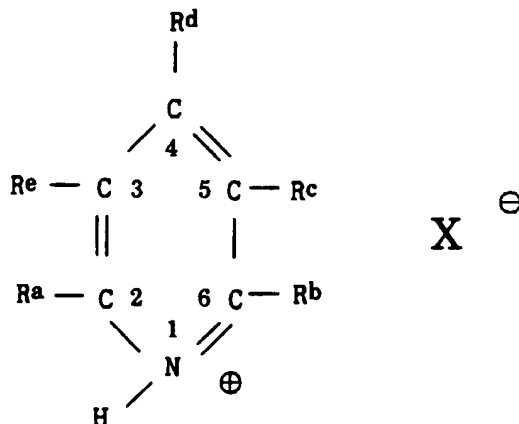


wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$  and  $R^e$  is previously defined in Formula VII; and X is the anion portion of an acid having

a weak nucleophilic anion.

Pyridinonium compounds represented by the following formula VIII'

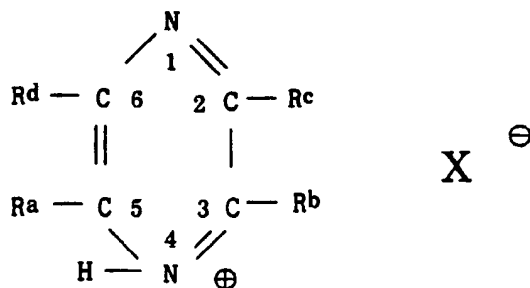
Formula VIII'.



wherein each  $\text{R}^a$ ,  $\text{R}^b$ ,  $\text{R}^c$ ,  $\text{R}^d$  and  $\text{R}^e$  is previously defined in Formula VIII; and X is the anion portion of an acid having a weak-nucleophilic anion.

Pyrazinonium compounds represented by the following formula IX'

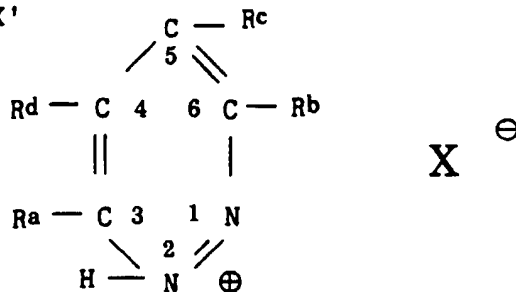
Formula IX'.



wherein each  $\text{R}^a$ ,  $\text{R}^b$ ,  $\text{R}^c$  and  $\text{R}^d$  is previously defined in Formula IX; and X is the anion portion of an acid having a weak nucleophilic anion.

Pyridazinonium compounds represented by the following formula X'

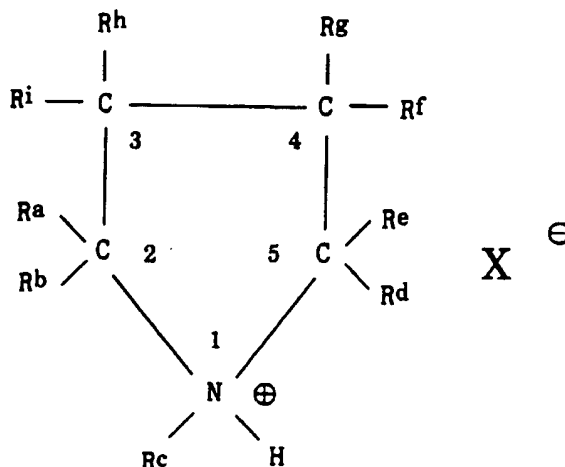
Formula X'



wherein each  $\text{R}^a$ ,  $\text{R}^b$ ,  $\text{R}^c$ , and  $\text{R}^d$  is previously defined in Formula X; and X is the anion portion of an acid having a weak nucleophilic anion.

Pyrrolidinonium compounds represented by the following formula XI'

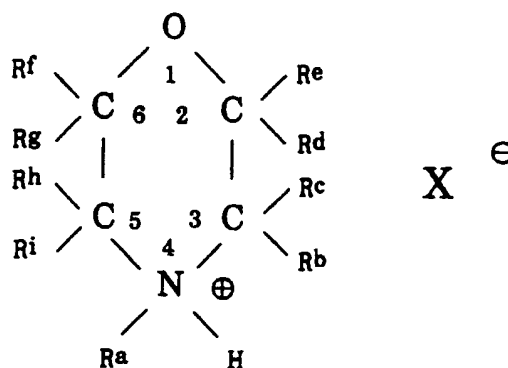
Formula XI'.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$  and  $R^i$  is previously defined in Formula XI; and X is the anion portion of an acid having a weak nucleophilic anion.

Morpholinonium compounds represented by the following formula XII'

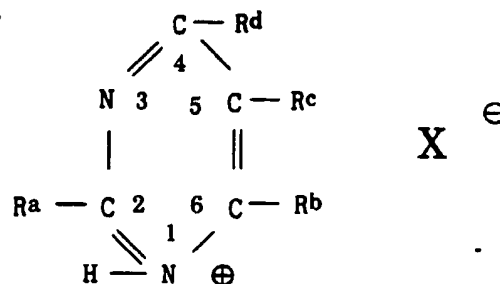
Formula XII'.



wherein  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$  and  $R^i$  is previously defined in Formula XII; and X is the anion portion of an acid having a weak-nucleophilic anion or a combination of such acids.

Pyrimidinonium compounds represented by the following formula XIII'

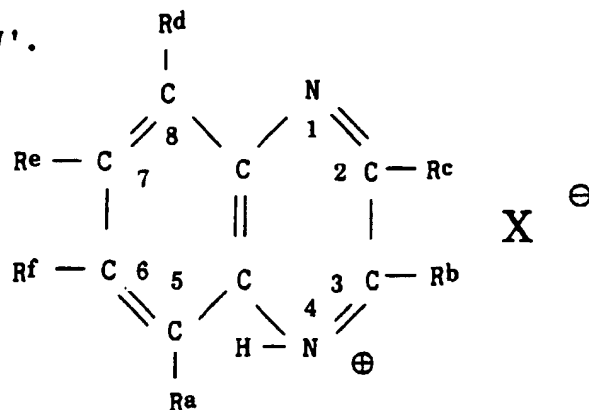
Formula XIII'.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$  and  $R^d$  is previously defined in Formula XIII; and X is the anion portion of an acid having a weak nucleophilic anion.

Quinoxalinonium compounds represented by the following formula XIV'

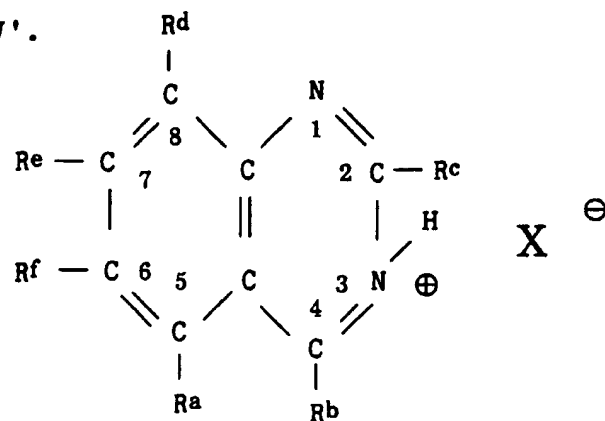
Formula XIV'.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, and R<sup>f</sup> is previously defined in Formula XIV; and X is the anion portion of an acid having a weak nucleophilic anion.

Quinazolinonium compounds represented by the following formula XV'

Formula XV'.

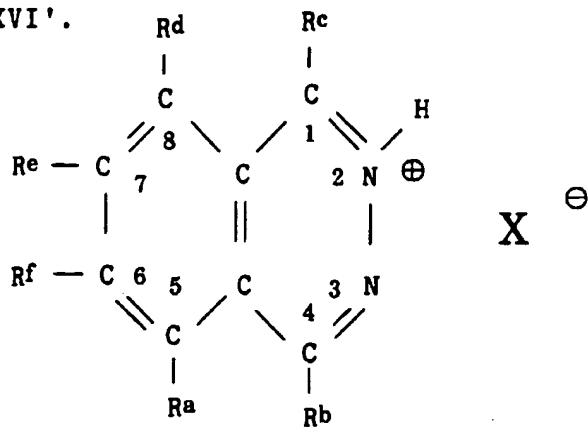


wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, and R<sup>f</sup> is previously defined in Formula XV; and X is the anion portion of an acid having a weak nucleophilic anion.

Phthalazinonium compounds represented by the following formula XVI'



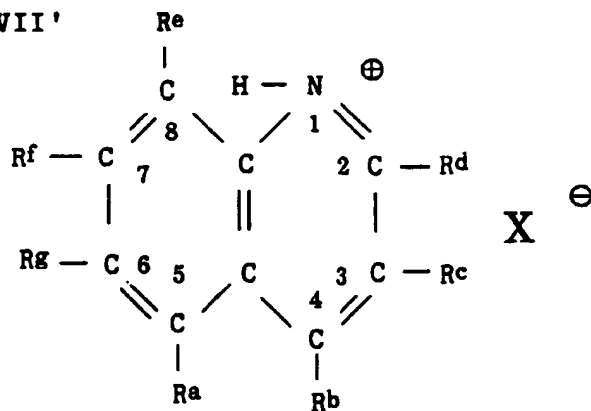
Formula XVI'.



20 wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ , and  $R^f$  is previously defined in Formula XVI; and X is the anion portion of an acid having a weak nucleophilic anion.

Quinolinonium compounds represented by the following formula XVII'

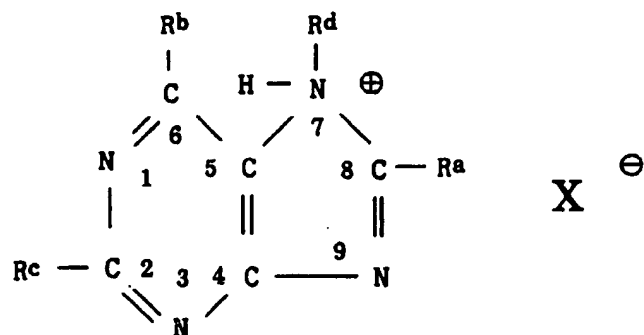
Formula XVII'



45 wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$  and  $R^g$  is previously defined in Formula XVII; and X is the anion portion of an acid having a weak nucleophilic anion.

Purinonium compounds represented by the following formula XVIII'

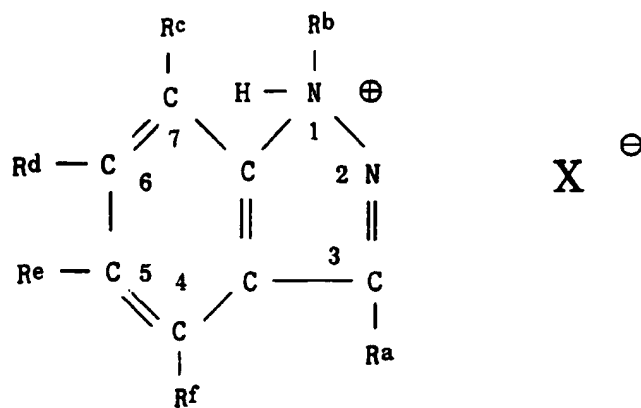
## Formula XVIII'.



wherein each  $R^a$ ,  $R^b$ ,  $R^c$  and  $R^d$  is previously defined in Formula XVIII; and X is the anion portion of an acid having a weak nucleophilic anion.

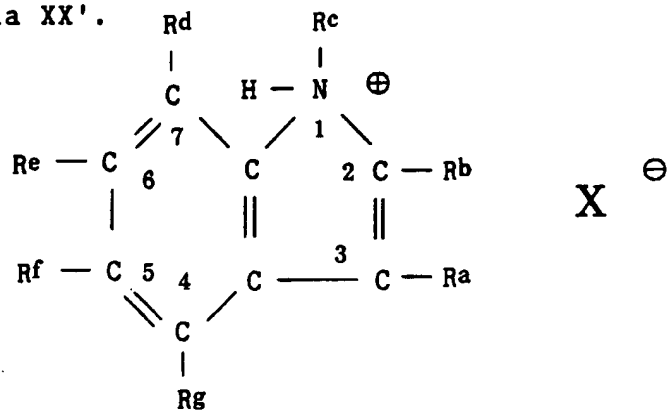
Indazolonium compounds represented by the following formula XIX'

## Formula XIX'.



Indolonium compounds represented by the following Formula XX'

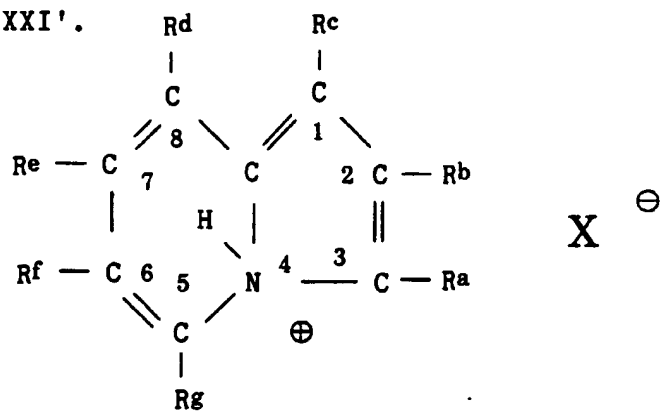
Formula XX'.



wherein each  $\text{R}^a$ ,  $\text{R}^b$ ,  $\text{R}^c$ ,  $\text{R}^d$ ,  $\text{R}^e$ ,  $\text{R}^f$  and  $\text{R}^g$  is previously defined in Formula XX; and X is the anion portion of an acid having a weak nucleophilic anion.

Indolizinonium compounds represented by the following formula XXI'

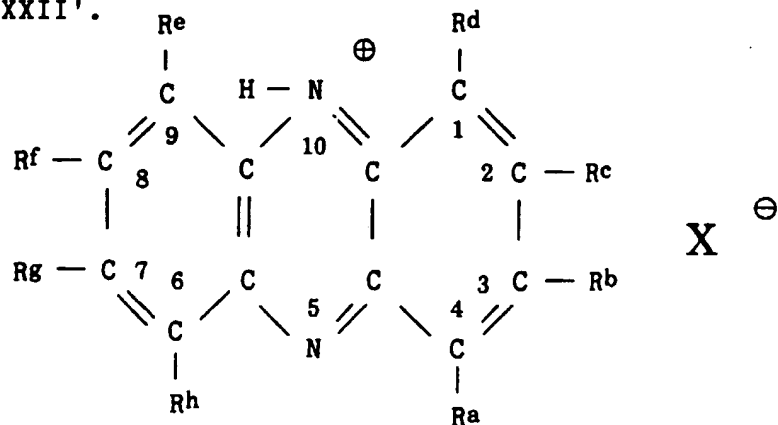
Formula XXI'.



wherein each  $\text{R}^a$ ,  $\text{R}^b$ ,  $\text{R}^c$ ,  $\text{R}^d$ ,  $\text{R}^e$ ,  $\text{R}^f$  and  $\text{R}^g$  is previously defined in Formula XXI; and X is the anion portion of an acid having a weak nucleophilic anion.

Phenazinonium compounds represented by the following formula XXII'

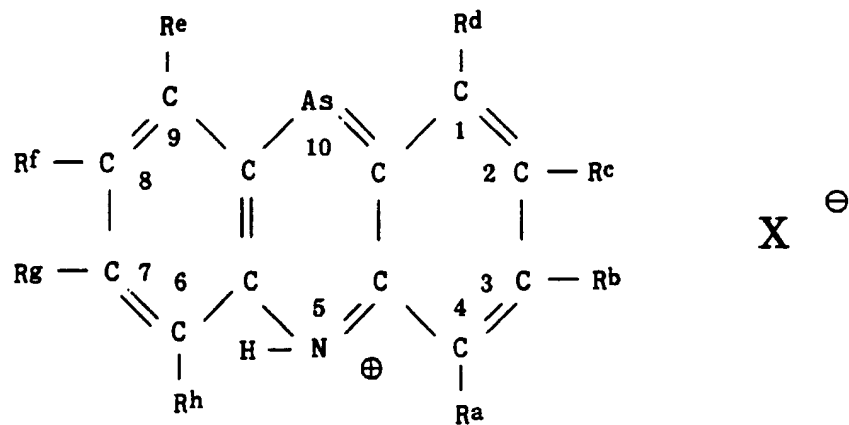
Formula XXII'.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup>, R<sup>g</sup> and R<sup>h</sup> is previously defined in Formula XXII and X is the anion portion of an acid having a weak nucleophilic anion.

Phenarsazonium compounds represented by the following formula XXIII'

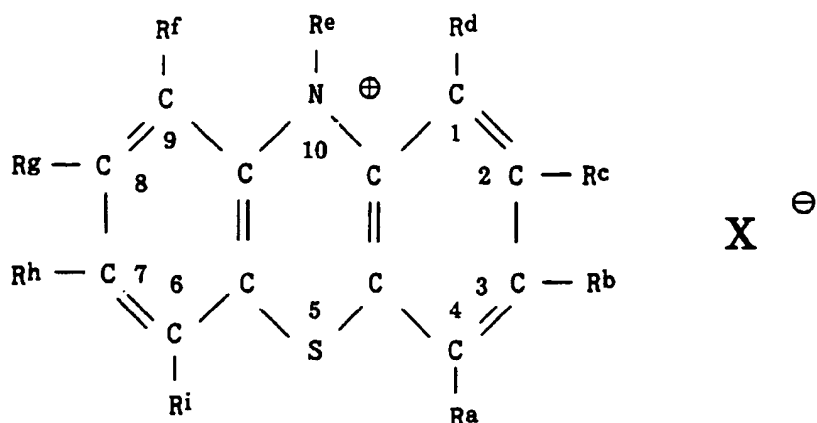
Formula XXIII'.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup>, R<sup>g</sup> and R<sup>h</sup> is previously defined in Formula XXIII; and X is the anion portion of an acid having a weak nucleophilic anion.

Phenothiazinonium compounds represented by the following formula XXIV'

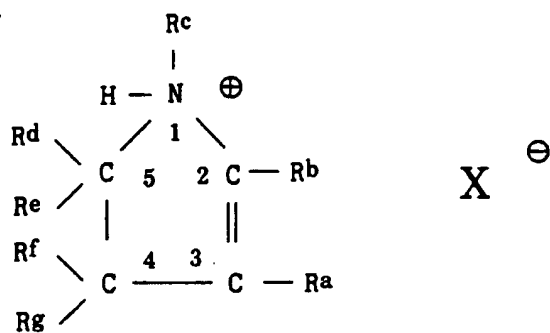
## Formula XXIV'.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup>, R<sup>g</sup>, R<sup>h</sup> and R<sup>i</sup> is previously defined in Formula XXIV; and X is the anion portion of an acid having a weak nucleophilic anion.

Pyrrolinonium compounds represented by the following formula XXV'

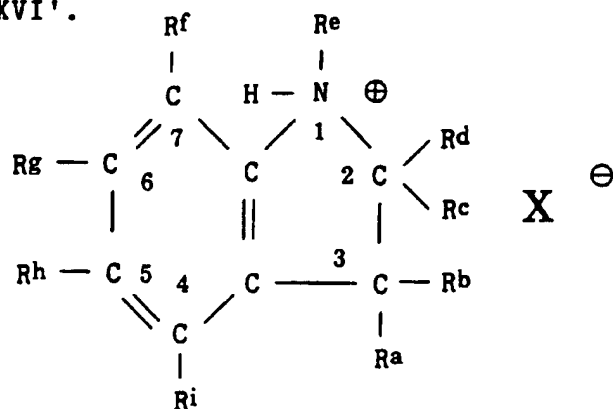
## Formula XXV'.



wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup> and R<sup>g</sup> is previously defined in Formula XXV; and X is the anion portion of an acid having a weak nucleophilic anion.

Indolinonium compounds represented by the following formula XXVI'

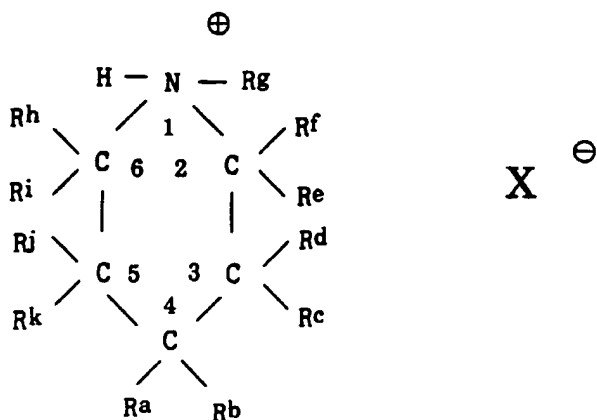
Formula XXVI'.



20 wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup>, R<sup>g</sup>, R<sup>h</sup> and R<sup>i</sup> is previously defined in Formula XXVI and X is the anion portion of an acid having a weak nucleophilic anion.

Piperidinonium compounds represented by the following formula XXVII'

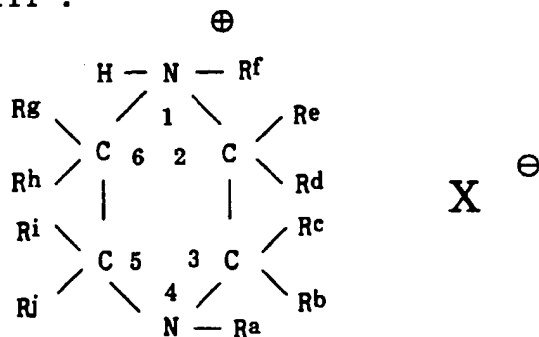
Formula XXVII'.



45 wherein each R<sup>a</sup>, R<sup>b</sup>, R<sup>c</sup>, R<sup>d</sup>, R<sup>e</sup>, R<sup>f</sup>, R<sup>g</sup>, R<sup>h</sup>, R<sup>i</sup>, R<sup>j</sup> and R<sup>k</sup> is previously defined in Formula XXVII and X is the anion portion of an acid having a weak nucleophilic anion.

Piperazinonium compounds represented by the following formula XXVIII'

Formula XXVIII'.

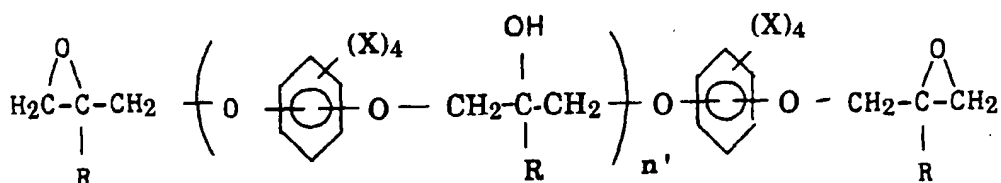


wherein each  $R^a$ ,  $R^b$ ,  $R^c$ ,  $R^d$ ,  $R^e$ ,  $R^f$ ,  $R^g$ ,  $R^h$ ,  $R^i$  and  $R^j$  is previously defined in Formula XXVIII; and X is the anion portion of an acid having a weak nucleophilic anion.

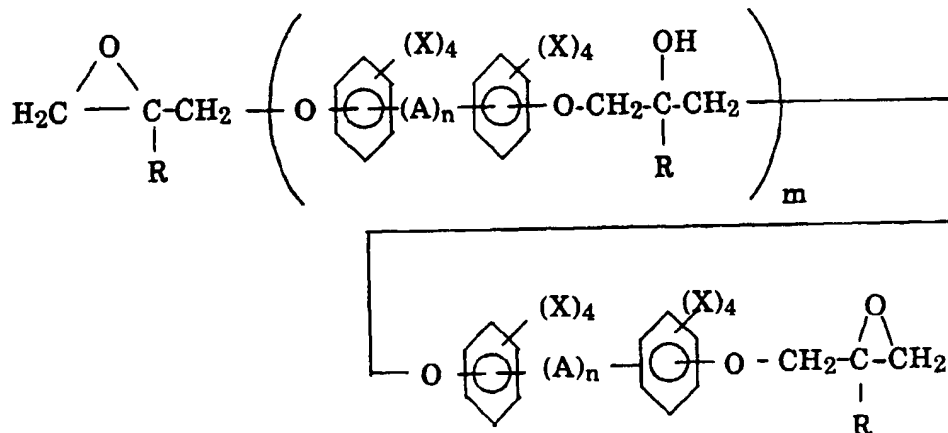
### Epoxy Containing Compounds

Suitable compounds having an average of more than one epoxide group per molecule which can be employed herein include, epoxy resins such as, for example, the glycidyl ethers of polyhydric phenols such as dihydroxy phenols, biphenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde novolac resins, substituted phenol-aldehyde novolac resins, phenol-hydrocarbon resins, substituted phenol-hydrocarbon resins, and any combination thereof. Suitable such epoxy resins include, for example, those represented by the following formulas A-E

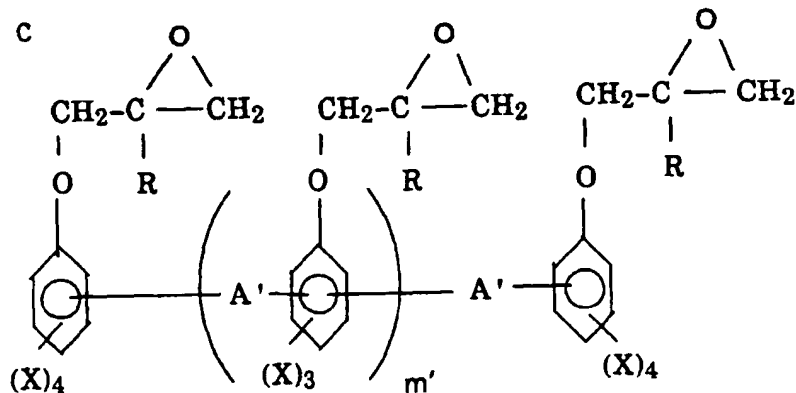
Formula A



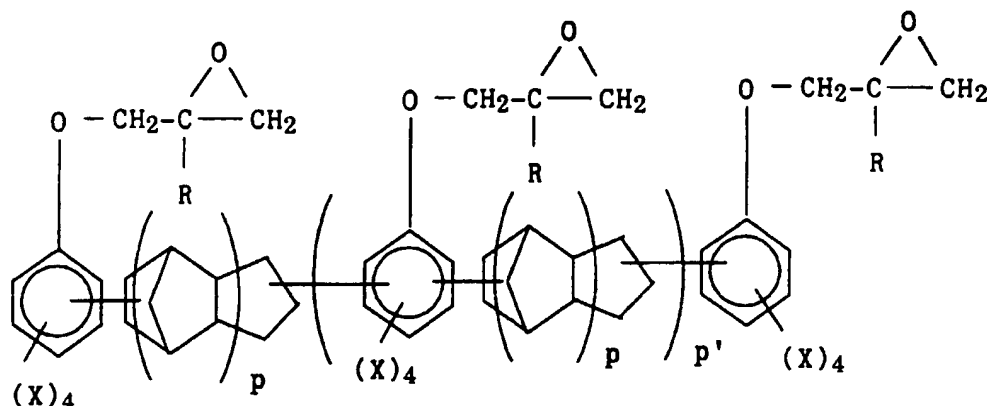
Formula B



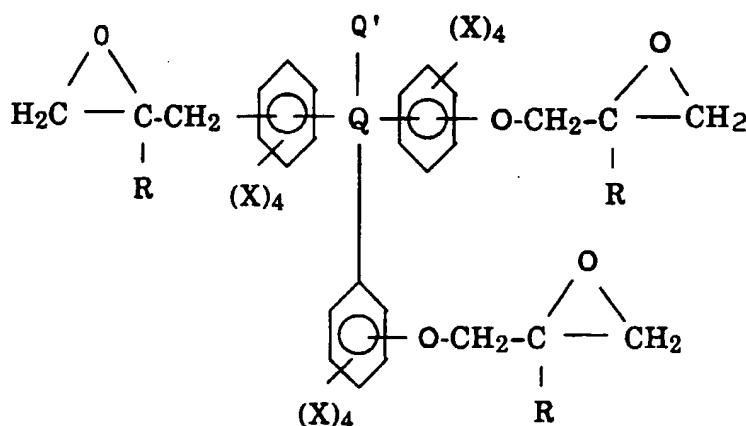
Formula C



Formula D



Formula E



wherein each A is independently a divalent hydrocarbyl group having from 1 to 9, preferably from 1 to 4, carbon atoms, -O-, -S-, -S-S-, -SO-, -SO<sub>2</sub>-, or -CO-; each A' is independently a divalent hydrocarbyl group having from 1 to 9, preferably from 1 to 4 carbon atoms; Q is a hydrocarbyl group having from 1 to 10 carbon atoms; Q' is hydrogen, halogen, cyano or an alkyl group having from 1 to 4 carbon atoms; each R is independently hydrogen, halogen, cyano or an alkyl group having from 1 to 4 carbon atoms; each X is independently hydrogen, bromine, chlorine, or a hydrocarbyl or hydrocarbyloxy group having from 1 to 9, preferably from 1 to 4 carbon atoms; m has an average value from zero to 12, preferably from zero to 9, most preferably from 0.03 to 3; m' has an average value from 0.01 to 8, preferably from 0.2 to 6, more preferably from 0.5 to 4; n has a value of zero or 1; n' has an average value of from zero to 12, preferably from zero to 9, most preferably from 0.03 to 3; each p suitably has a value from zero to 10, more suitably from zero to 6, most suitably from 1 to 3; and each p' suitably has a value from zero to 8, more suitably from 1 to 6, most suitably from 2 to 4. Also suitable are the oligomers of the epoxy resin represented by formula E.

The term hydrocarbyl as employed herein means any aliphatic, cycloaliphatic, aromatic, aryl substituted aliphatic or cycloaliphatic, or aliphatic or cycloaliphatic substituted aromatic groups. The aliphatic groups can be saturated or unsaturated. Likewise, the term hydrocarbyloxy means a hydrocarbyl group having an oxygen linkage between it and the carbon atom to which it is attached.

Particularly suitable such epoxy resins include, for example, the diglycidyl ethers of resorcinol, catechol, hydroquinone, biphenol, bisphenol A, bisphenol F, bisphenol K, tetrabromobisphenol A, phenol-formaldehyde novolac resins,



alkyl substituted phenol-formaldehyde resins, phenol-hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde resins, dicyclopentadiene-phenol resins, dicyclopentadiene-substituted phenol resins, tetramethylbiphenol, tetramethyl-tetrabromobiphenol, tetramethyltribromobiphenol, tetrachlorobisphenol A, and any combination thereof.

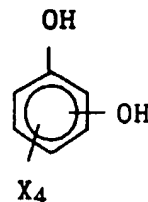
Also suitable as the epoxide compound which can be employed in the present invention include those partially advanced epoxy resins disclosed by Bertram et al. in U.S. Patent 4,594,291.

Also suitable as the epoxide compound are the glycidyl ethers of compounds having an average of more than one aliphatic hydroxyl group per molecule such as, for example, aliphatic diols, polyether diols, polyether triols, polyether tetrols, and any combination thereof. Also suitable are the alkylene oxide adducts of compounds containing an average of more than one aromatic hydroxyl group per molecule such as, for example, the ethylene oxide, propylene oxide, or butylene oxide adducts of dihydroxy phenols, biphenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde novolac resins, halogenated phenol-aldehyde novolac resins, alkylated phenol-aldehyde novolac resins, hydrocarbon-phenol resins, hydrocarbon-halogenated phenol resins, or hydrocarbon-alkylated phenol resins, or and any combination thereof.

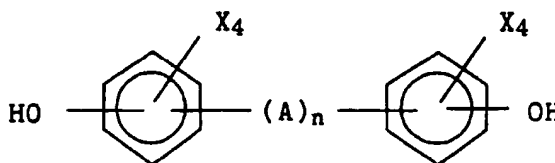
#### Aromatic Hydroxyl Containing Compounds

Suitable aromatic hydroxyl containing compounds which can be employed herein include, for example, compounds having an average of more than one phenolic hydroxyl group per molecule. Suitable such compounds include, for example, dihydroxy phenols, biphenols, bisphenols, halogenated bisphenols, alkylated bisphenols, trisphenols, phenol-aldehyde resins, halogenated phenol-aldehyde novolac resins, alkylated phenol-aldehyde novolac resins, phenol-hydroxybenzaldehyde resins, alkylated phenol-hydroxybenzaldehyde resins, hydrocarbon-phenol resins, hydrocarbon-halogenated phenol resins, hydrocarbon-alkylated phenol resins, and any combination thereof. Particularly suitable aromatic hydroxyl containing compounds include, for example, those represented by the following formulas F-I.

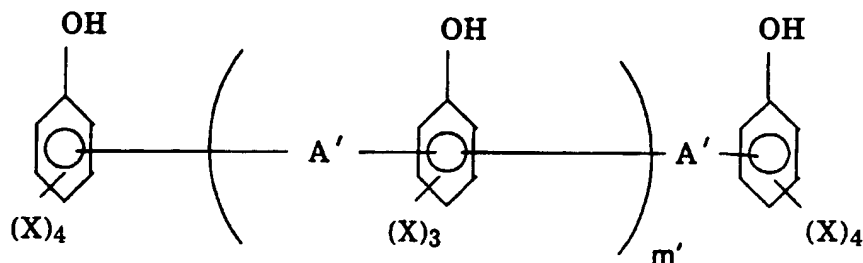
**Formula F**



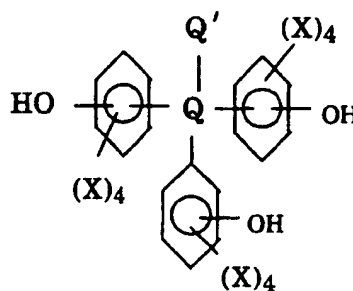
**Formula G**



Formula H



Formula I



wherein A, A', Q, Q', X, n and m are as defined above in formulas A-E. Particularly suitable aromatic hydroxyl-containing materials include, for example, biphenol, bisphenol A, bisphenol K, tetrabromobisphenol A, tetrabromobisphenol K, resorcinol, phenol-aldehyde novolac resins, cresol-aldehyde novolac resins, phenol-hydroxybenzaldehyde resins, cresol-hydroxybenzaldehyde resins, tetramethylbiphenol, tetramethyltribromobiphenol, tetramethyltetrabromobiphenol, tetrachlorobisphenol A, and any combination thereof. Also suitable are the oligomers of the multifunctional phenolic compounds represented by the formula I.

These and other suitable aromatic hydroxyl-containing compounds are disclosed in U.S. Patent No. 4,594,291 issued June 10, 1986 by Bertram et al.

The aromatic hydroxyl-containing compounds are employed in amounts which provide a ratio of aromatic hydroxyl groups to epoxy groups suitably from 0.05:1 to 20:1, more suitably from 0.1:1 to 10:1, most suitably from 0.2:1 to 5:1.

The precatalyzed compositions of the present invention can contain, if desired, pigments, fillers, dyes, diluents, stabilizers, epoxy resin curing agents, and any combination thereof.

Suitable stabilizer materials and curing agents which can be employed herein include, for example, those disclosed in the aforementioned U.S. Patent No. 4,594,291 by Bertram et al.

The present compositions are useful in the preparation of formulations for use in the preparation of electrical and structural laminates and composites, coatings, and the like.

#### Examples

The following examples are illustrative of the invention.

#### Example 1 PREPARATION OF 2-METHYLIMIDAZOLIUM FLUOBORATE COMPLEX

A glass flask fitted with a stirrer, thermometer, and reflux condenser was charged with 15.37 grams (0.098 mole) of a 55.9 percent aqueous solution, by weight, of fluoboric acid. To this stirred solution, 8.2 grams (0.100 mole) of 2-methylimidazole were slowly added during about five minutes. The heat from the reaction warmed the solution to approximately 50°C as the 2-methylimidazole dissolved. The solution was stirred for an additional 30 minutes as it cools to near ambient temperature. Methanol was then added, 19.98 grams, to dilute the solution to 38.6 percent solids based on the weight of the 2-methylimidazole and fluoboric acid.

The concentration of the aqueous fluoboric acid was determined by potentiometric titration to the first inflection

point with 0.100 N potassium hydroxide in methanol. An MCI GT-05 automatic titrator and a combination silver/silver chloride electrode (Curtain Matheson Scientific No. 201-947) were used to measure the pH changes during the course of the titration.

#### Examples 2-12 PREPARATION OF 2-METHYLIMIDAZOLIUM FLUOBORATE COMPLEXES

The procedure described in Example 1 was repeated using the same procedure and amount of 2-methylimidazole (2-MI), however the weight of fluoboric acid (55.9 percent aqueous solution) was varied as shown in Table I. All experiments were diluted with methanol to 38.5 percent solids based on the combined weights of 2-MI and fluoboric acid. The results are given in Table I.

Table I

2-METHYLIMIDAZOLE WITH VARYING RATIOS OF FLUOBORIC ACID		
Example Number	Fluoboric Acid Solution (grams)	Moles of Fluoboric Acid Per Mole of 2-MI
2	11.71	0.75
3	13.17	0.84
4	13.90	0.89
5	14.63	0.93
1	15.37	0.98
6	16.10	1.03
7	16.83	1.07
8	17.56	1.12
9	17.88	1.14
10	18.35	1.17
11	20.39	1.30
12	21.17	1.35

#### Example 13 PREPARATION OF 2-PHENYLIMIDAZOLIUM FLUOBORATE

A glass flask fitted with a stirrer, thermometer, and reflux condenser was charged with 15.37 grams (0.098 mole) of a 55.9 percent aqueous solution, by weight, of fluoboric acid and 29.3 grams of methanol. To this stirred solution, 14.4 grams (0.100 mole) of 2-phenylimidazole (2-PI) were slowly added during about five minutes. The heat from the reaction warmed the solution to approximately 50°C as the 2-phenylimidazole dissolved. The solution was stirred for an additional 30 minutes as it cooled to near ambient. The product was a clear solution containing 38.9 percent by weight of the 2-phenylimidazolium fluoborate adduct/complex.

#### Example 14 PREPARATION OF 4-METHYLIMIDAZOLIUM FLUOBORATE COMPLEX

The procedure of Example 13 was followed using the following reagents:

4.00 g (0.0487 mole) of 4-methylimidazole (4-MI)  
 7.84 g (0.0500 mole) of fluoboric acid (55.9 percent aqueous)  
 9.92 g of methanol

The resultant product was a clear solution containing 38.5 percent by weight of the 4-methylimidazolium fluoborate adduct/complex.

#### Example 15 PREPARATION OF 1,2-DIMETHYLIMIDAZOLIUM FLUOBORATE COMPLEX

The procedure of Example 13 was followed using the following reagents:

4.68 g (0.0487 mole) of 1,2-dimethylimidazole (1,2-DMI)  
 7.84 g (0.0500 mole) of fluoboric acid (55.9 percent aqueous)  
 10.95 g of methanol

- 5 The resultant product was a clear solution containing 38.6 percent by weight of the 1,2-dimethylimidazolium fluoborate adduct/complex.

#### Example 16 PREPARATION OF 2-ETHYL-4-METHYLMIDAZOLIUM FLUOBORATE COMPLEX

- 10 The procedure of Example 13 was followed using the following reagents:

5.36 g (0.0487 mole) of 2-ethyl-4-methylimidazole (2-E-4-MI)  
 7.84 g (0.0500 mole) of fluoboric acid (55.9 percent aqueous)  
 11.98 g of methanol

- 15 The resultant product was a clear solution containing 38.7 percent by weight of the 2-ethyl-4-methylimidazolium fluoborate adduct/complex.

#### Example 17 PREPARATION OF 4,5-DIPHENYLMIDAZOLIUM FLUOBORATE COMPLEX

- 20 The procedure of Example 13 was followed using the following reagents:

4.00 g (0.0182 mole) of 4,5-diphenylimidazole (4,5-DPI)  
 2.92 g (0.0166 mole) of fluoboric acid (55.9 percent aqueous)  
 7.47 g of methanol

- 25 After the above reactants were added together, the mixture was not homogeneous, therefore an additional 35.4 grams of the monomethyl ether of propylene glycol monoacetate was added to give a clear solution containing 11.3 percent by weight of the 4,5-diphenylimidazolium fluoborate adduct/complex.

#### Examples 18 - 29 IMIDAZOLIUM FLUOBORATE COMPLEX CATALYZED EPOXY/PHENOLIC SYSTEMS

- 30 The catalysts described in Examples 1 - 17 were mixed with a 1:1 molar ratio of a diglycidyl ether of bisphenol A having an epoxy equivalent weight of 181.5 and bisphenol A (2,2-bis(-hydroxyphenyl)-propane), dissolved in the monomethylether of propylene glycol monoacetate (PMA). The epoxy resin (181.5 grams, 1 equiv.), bisphenol A (114 grams, 1 equiv.) and 73.88 grams of PMA are heated between 80°C and 100°C under a nitrogen atmosphere until homogeneous, cooled to ambient temperature and the appropriate amount of catalyst added as described in Table II. Portions of these solutions were then stored at 50°C and the 25°C viscosity monitored as shown in Table III.

Table II

CATALYZED EPOXY/PHENOLIC FORMULATIONS			
Example or Comp. Expt. No.	Catalyst (Ex. Number)	Catalyst Solution Weight (grams)	Millimoles of Catalyst per Equivalent of Epoxide
18	1	3.92	9.0
19	3	3.67	9.0
20	4	3.75	9.0
21	5	3.82	9.0
22	6	4.02	9.0
23	7	4.12	9.0
24	8	4.22	9.0
25	9	4.24	9.0
26*	10	4.31	9.0

\*Not an example of the present invention.

Table II (continued)

CATALYZED EPOXY/PHENOLIC FORMULATIONS			
Example or Comp. Expt. No.	Catalyst (Ex. Number)	Catalyst Solution Weight (grams)	Millimoles of Catalyst per Equivalent of Epoxide
27*	11	4.59	9.0
28*	12	4.67	9.0
29	15	4.33	9.0
C. E. <sup>a</sup> A*	No Cat.	-----	-----
C. E. <sup>a</sup> B*	2-MI <sup>b</sup>	1.85	9.0
C. E. <sup>a</sup> C*	2-PI <sup>c</sup>	3.24	9.0
C. E. <sup>a</sup> D*	1,2-DMI <sup>d</sup>	2.16	9.0

<sup>a</sup>C. E. is Comparative Experiment.<sup>b</sup>2-methyl imidazole alone as catalyst. (40% by wt. solution in methanol)<sup>c</sup>2-phenylimidazole alone as catalyst. (40% by vvt. solution in methanol)<sup>d</sup>1,2-dimethylimidazole alone as catalyst. (40% by wt. solution in methanol)

Table III - 50°C Stability Study

Ex. or CEa	Nitrogen or Phosphorus Cont. Compound	Mol. Of HBF <sub>4</sub> per Mol. of N- Cont. Cmpd.	Viscosity						% of Control Viscosity	
			Initial		After 1 Day		After 14 Days		After 1 Day	After 14 Days
					Cps	Pa.s	Cps	Pa.s		
			Cps	Pa.s						
18	2-MI	0.98	885	.885	1054	1.054	1385	1.385	10.5	<0.7
19	2-MI	0.84	904	.904	1211	1.211	24150	24.150	12.1	<12.1
20	2-MI	0.89	891	.891	1144	1.144	8890	8.890	11.4	<4.4
21	2-MI	0.93	887	.887	1085	1.085	3120	3.120	10.8	<1.6
22	2-MI	1.03	877	.887	1032	1.032	1251	1.251	10.3	<0.6
23	2-MI	1.07	840	.840	957	.957	1168	1.168	9.6	<0.6
24	2-MI	1.12	836	.836	987	.987	2919	2.919	9.9	<1.5
25*	2-MI	1.14	1360	1.360	>200,000 <sup>b</sup>	>200 <sup>b</sup>	N.D.	N.D.	N/A	N.D.

Table III (contd.) - 50°C Stability Study

Ex. or CEa	Nitrogen or Phosphorus Cont. Compound	Mol. of HBF <sub>4</sub> per Mol. of N- Cont. Cmpd.	Viscosity						% of Control Viscosity	
			Initial		After 1 Day		After 14 Days			
			Cps	Pa.s	Cps	Pa.s	Cps	Pa.s	After 1 Day	After 14 Days
26*	2-MI	1.17	1243	1.243	>200,000b	>200b	---	---	>1999	---
27*	2-MI	1.30	1715	1.715	>200,000b	>200b	---	---	>1999	---
28*	2-MI	1.35	2000e	2.000e	>200,000b	>200b	---	---	>1999	---
29	1,2-DMI	1.03	836	.836	932	.932	1260	1.260	7.6	<0.6

Table III (contd.) - 50°C Stability Study

Ex. or CEa	Nitrogen or Phosphorus Cont. Compound	Mol. of HBF <sub>4</sub> per Mol. of N- Cont. Cmpd.	Viscosity						% of Control Viscosity	
			Initial		After 1 Day		After 14 Days		After 1 Day	After 14 Days
			Cps	Pa.s	Cps	Pa.s	Cps	Pa.s		
A*	None	0	1079	1.079	1081	1.081	1256	1.256	---	---
B*	2-Mic	0	1006	1.006	10,006	10.006	>200,000b	>200b	---	---
C*	2-Pic	0	1042	1.042	14,000	14.000	---	---	---	---
D*	1,2-DMic	0	1171	1.171	12,228	12.228	>200,000b	>200b	---	---



FOOTNOTES TO TABLE III

- 5 Not an example of the present invention.
- a Examples are designated by numerals whereas comparative experiments are designated by letters.
- 10 b Viscosity of the composition exceeded the test method ( $>200,000$  cps).
- c 2-Methylimidazole, 2-phenylimidazole and 1,2-dimethylimidazole employed alone as catalyst.
- 15 d This value was determined by dividing the viscosity obtained in the appropriate example by the viscosity of a comparable formulation employing as the catalyst the same nitrogen or phosphorus compound except that it had not been reacted with  $\text{HBF}_4$ .
- 20 e The viscosity was increasing during measurement.

Example 30 COATING PROPERTIES WITH 2-METHYL-IMIDAZOLIUM FLUOBORATE CATALYST

25 The formulations described in Example 18 and Comparative Experiment B were applied to 24 gauge Bonderite™ R 90 treated steel panels available from Parker Chemical Co. via a wire wound steel draw down rod. The coatings were allowed to air dry for approximately five minutes, then placed in a forced air oven preset at  $200^\circ\text{C}$  for 10 minutes. The panels were removed from the oven, cooled to ambient temperature, and tested as shown in Table IV.

30 Resistance to methyl ethyl ketone was determined in the following manner. The ball end of a ball peen hammer weighing about 1.5 lbs. (0.6804 kg) was covered with 8 plies of gauze, which was then wet with methyl ethyl ketone (MEK). The ball end of the hammer was applied to the coated surface and rubbed back and forth until the coating was removed. One double rub corresponded to one back and forth movement of the hammer. The number of double rubs required to remove or mar the coating was recorded.

35 Flexibility was determined by a 1/8 in. (3.175 mm) wedge test using a Gardner Falling Dart Impact Tester (available from the Gardner Laboratory, Inc., Bethesda, Maryland) configured for 0 to 1/8 in. (0 to 3.175 mm) wedge bend test. The bottom 3/4 in. (19.05 mm) of the panel was bent  $180^\circ$  over itself, exposing the coating to the outer surface, then sandwiched between two non-parallel steel plates that were hinged such that when completely together, they form a zero to 1/8 in. (0 to 3.175 mm) gap. The top plate was then impacted with the blunt end of the falling dart until the panel was bent from a zero to 1/8 in. (0 to 3.175 mm) wedge. The coated area over the bend was then wiped for approximately one minute with a 10 percent  $\text{CuSO}_4/1\text{N HCl}$  solution which turned a copper-red color where the coating had failed and exposed steel metal. The percent pass value given in Table IV was calculated as the number of inches from the 1/8 in. (0 to 3.175 mm) end to the point of failure, as evidenced by the copper-red color, divided by the total 4 in. (101.6 mm) total length times 100.

Table IV

COATING PROPERTIES OF CATALYZED SYSTEMS					
SAMPLE NUMBER	FORMULATIONS FROM EXAMPLE OR COMP. EXPT.	MEK DOUBLE RUBS	GARDNER IMPACT		1/8 in. WEDGE BEND % Pass
			in. - lbs.	J	
I	18	30-50	$> 180$	$> 20.34$	100
II*	C.E. <sup>a</sup> B	$> 100$	$> 180$	$> 20.34$	100

\*Not an example of the present invention.

<sup>a</sup>C.E. is Comparative Experiment.

**Example 31 PREPARATION OF ETHYLTRIPHENYLPHOSPHONIUM FLUOBORATE COMPLEX**

A glass flask fitted with a stirrer, thermometer, and reflux condenser was charged with 11.4 grams of a 71.9 percent methanol solution, by weight, of ethyltriphenylphosphonium acetate-acetic acid (ETPPA-HAc) complex (0.0200 moles). To this stirred solution, 3.682 grams (0.0224 moles) of a 53.4 percent by weight aqueous solution of fluoboric acid (1.12 moles per mole of ETPPA-HAc) were slowly added during about five minutes. The heat from the reaction warmed the solution to approximately 50°C. The solution was stirred for an additional 30 minutes as it cooled to near ambient temperature. Methanol was then added, 10.22 grams, to dilute the solution to 40 percent solids based on the weight of the ethyltriphenylphosphonium fluoborate complex.

The weight percent of ETPPA-HAc in methanol was determined by titration of the acetate group with 0.1006 N perchloric acid (HC10<sub>4</sub>) in acetic acid to a crystal violet endpoint (blue to green endpoint). It required 12.80 ml (0.001280 moles) of perchloric acid solution to titrate 0.7295 g of ETPPA-HAc/methanol solution dissolved in 15 ml of dichloromethane, which calculated to 71.9 weight percent of ETPPA-HAc in methanol.

**Examples 32-36-45 PREPARATION OF ETHYLTRIPHENYLPHOSPHONIUM FLUOBORATE COMPLEXES**

The procedure described in Example 31 was repeated using the same procedure and amount of ETPPA-HAc, however the weight of fluoboric acid (53.4 percent aqueous solution) was varied as shown in Table IV. All experiments were diluted with methanol to 40 percent solids based on the combined weights of ETPPA-HAc and fluoboric acid.

TABLE IV

ETHYLTRIPHENYLPHOSPHONIUM FLUOBORATE COMPLEXES WITH VARYING RATIOS OF FLUOBORIC ACID		
EXAMPLE NUMBER	FLUOBORIC ACID SOL. (grams)	MOLES FLUOBORIC ACID PER MOLE OF ETPPA-HAc
32	3.353	1.02
33	3.517	1.07
34	3.682	1.12
35	3.876	1.17
36	4.010	1.22
C.E. <sup>a</sup> E*	0.0 <sup>b</sup>	0.0

\*Not an example of the present invention.

<sup>a</sup>C.E. is Comparative Experiment.

<sup>b</sup>Ethyltriphenylphosphonium acetate-acetic acid complex alone as catalyst.

**Example 37 PREPARATION OF TETRABUTYLPHOSPHONIUM FLUOBORATE COMPLEX**

A glass flask fitted with a stirrer, thermometer, and reflux condenser was charged with 6.20 grams (0.01 moles) of a 60.9 percent methanol solution, by weight, of tetrabutylphosphonium acetate-acetic acid complex (TBPA-HAc). To this stirred solution, 2.00 grams (0.0122 moles) of a 53.4 percent by weight aqueous solution of fluoboric acid (1.22 moles per mole of TBPA-HAc) were slowly added during about five minutes. The heat from the reaction warmed the solution to approximately 50°C. The solution was stirred for an additional 30 minutes as it cooled to near ambient temperature. Methanol was then added, 3.916 grams, to dilute the solution to 40 percent solids based on the weight of the tetrabutylphosphonium fluoborate complex.

The weight percent of TBPA-HAc in methanol was determined by titration of the acetate group with 0.1006 N perchloric acid (HC10<sub>4</sub>) in acetic acid to a crystal violet endpoint (blue to green endpoint). It required 10.15 ml (0.001015 moles) of perchloric acid solution to titrate 0.6301 g of TBPA-HAc/methanol dissolved in 15 ml of dichloromethane, which calculated to 60.9 weight percent TBPA-HAc in methanol.

**Examples 38-42 PREPARATION OF TETRABUTYLPHOSPHONIUM FLUOBORATE COMPLEXES**

The procedure described in Example 37 was repeated using the same procedure and amount of tetrabutylphosphonium acetate-acetic acid complex (TBPA-HAc), however the weight of fluoboric acid (53.42 percent aqueous solution) was varied as shown in Table V. All experiments were diluted with methanol to 40 percent solids based on the

combined weights of TBPA.HAc and fluoboric acid.

TABLE V

TETRABUTYLPHOSPHONIUM FLUOBORATE COMPLEXES WITH VARYING RATIOS OF FLUOBORIC ACID		
EXAMPLE NUMBER	FLUOBORIC ACID SOL. (grams)	MOLES FLUOBORIC ACID PER MOLE OF TBPA.HAc
38	1.759	1.07
39	1.84	1.12
40	1.923	1.17
37	2.005	1.22
41	2.087	1.27
42	2.17	1.32
C.E. <sup>a</sup> F*	0.0 <sup>b</sup>	0.0

\*Not an example of the present invention.

<sup>a</sup>C.E. is Comparative Experiment.

<sup>b</sup>Tetrabutylphosphonium acetate-acetic acid complex alone as catalyst.

#### Examples 43-44 PREPARATION OF OTHER FLUOBORATE COMPLEXES

The procedure of Example 31 was followed, using a ratio of 1.02 moles of fluoboric acid per equivalent of nitrogen containing compound as described in Table VI. Methanol was added to bring the percent solids based on the amine compound-fluoborate complex to 40 percent by weight.

TABLE VI

TETRABUTYLPHOSPHONIUM FLUOBORATE COMPLEXES WITH VARYING RATIOS OF FLUOBORIC ACID	
EXAMPLE NUMBER	NITROGEN CONTAINING COMPOUND
43	N-METHYLMORPHOLINE
44	DIBUTYLAMINE

#### Example 45 FLUOBORATE COMPLEX VIA SILVER FLUOBORATE

Vacuum dried tetrabutylphosphonium chloride, 1.82 grams (0.0062 moles) was dissolved in 5.84 grams of methanol and added dropwise to 1.20 grams (0.0062 moles) of silver fluoborate dissolved in 3.46 grams of methanol. The suspension was stirred at 25°C for 30 minutes, and the silver chloride removed by filtration. The tetrabutylphosphonium fluoborate solution was concentrated to 40 percent solids by weight via vacuum removal of the excess methanol.

#### Example 46 FLUOBORATE COMPLEX CATALYZED EPOXY/PHENOLIC SYSTEMS

The catalysts described in Examples 38 to 64 were mixed with a 1:1 molar ratio of a diglycidyl ether of bisphenol A having an epoxy equivalent weight of 181.5 and bisphenol A (2,2-bis(4,4'-hydroxyphenyl)-propane, dissolved in the monomethylether of propylene glycol monoacetate (PMA). The epoxy resin (181.5 grams), bisphenol A (114 grams) and 73.88 grams of PMA were heated to 80-100°C under a nitrogen atmosphere until homogeneous, cooled to ambient temperature and 9.0 millimoles of catalyst added to 1.00 equivalent of epoxide in a manner that is described previously for Examples 18-29. Portions of these solutions were then stored at 50°C and the 25°C viscosity monitored as shown in Table VII.

Table VII - 50°C Stability Study

Cat- alyst from Ex. or CEa	Phosphorus Cont. Compound	Mol. of HBF <sub>4</sub> per Mol. of P Cont. Cmpd.	Viscosity						% of Control Viscosityf	
			Initial		After 1 Day		After 14 Days		After 1 Day	After 14 Days
			Cps	Pa.s	Cps	Pa.s	Cps	Pa.s		
32	ETPPA.HAc	1.02	366	.366	408	.408	13565	13.565	<0.2	<6.8
33	ETPPA.HAc	1.07	356	.356	385	.385	1014	1.014	<0.2	<0.5
34	ETPPA.HAc	1.12	348	.348	370	.370	543	.543	<0.2	<0.3
35	ETPPA.HAc	1.17	348	.348	391	.391	623	.623	<0.2	<0.3
36	ETPPA.HAc	1.22	436	.436	749	.749	1352	1.352	<0.4	<0.7

Table VII (contd.) - 50°C Stability Study

Cat- alyst from Ex. or CEa	Phosphorus Cont. Compound	Mol. of HBF <sub>4</sub> per Mol. of P Cont. Cmpd.	Viscosity						% of Control Viscosityf	
			Initial		After 1 Day		After 14 Days		After 1 Day	After 14 Days
			Cps	Pa.s	Cps	Pa.s	Cps	Pa.s		
38	TBPA·HAC	1.07	383	.383	444	.444	24378	24.378	.9	12.2
39	TBPA·HAC	1.12	377	.377	430	.430	6490	6.490	.9	3.2
40	TBPA·HAC	1.17	387	.387	407	.407	733	.733	.9	.4
37	TBPA·HAC	1.22	376	.376	393	.393	572	.572	.8	.3
41	TBPA·HAC	1.27	385	.385	462	.462	841	.841	1.0	.4
42	TBPA·HAC	1.32	407	.407	936	.936	5900	5.900	2.0	3.0

Table VII (contd.) - 50°C Stability Study

Cat- alyst from E x. or CE <sup>a</sup>	Nitrogen Cont. Compound	Mol. of HBF <sub>4</sub> per Mol. of N Cont. Compd.	Viscosity						% of Control Viscosity <sup>f</sup>	
			Initial		After 1 Day		After 14 Days		After 1 Day	After 14 Days
			Cps	Pa.s	Cps	Pa.s	Cps	Pa.s		
43	N-methyl morpholine	1.03	718	0.718	845	0.845	1113	1.113	3.1	<5.6
44	Dibutyl amine	1.03	602	.602	684	0.684	1049	1.049	3.4	.5
C.E.I *	4-Phenyl morpholine	1.03	688	.688	>2000g	>200g	----	----	----	----

Table VII (contd.) - 50°C Stability Study

Cat- alyst from Ex. or CEa	Nitrogen Cont. Compound	Mol. of HBF <sub>4</sub> per Mol. of N Cont. Cmpd.	Viscosity						% of Control Viscosity <sup>f</sup>	
			Initial		After 1 Day		After 14 Days		After 1 Day	After 14 Days
			Cps	Pa.s	Cps	Pa.s	Cps	Pa.s		
C.E.aE*	ETPPA.HAc <sup>b</sup>	0	1053	1.053	>200,000g	>200	---	---	---	---
C.E.aF*	TBPA.HAc <sup>c</sup>	0	898	.898	47,577	47.557	>200,000g	>200	---	---
C.E.aG*	Dibutylamine <sup>d</sup>	0	1169	1.169	20,328	20.328	>200,000g	>200	---	---
C.E.aH*	N-Methyl- morpholine <sup>e</sup>	0	1330	1.330	26,999	26.999	>200,000g	>200	---	---

\* Not an example of the present invention.

a Examples are designated by numerals whereas comparative experiments are designated by letters.

b Ethyltriphenylphosphonium acetate-acetic acid complex employed alone as catalyst.

c Tetraethylphosphonium acetate-acetic acid complex employed alone as catalyst.

d Dibutylamine employed alone as catalyst.

e N-methylmorpholine employed alone as catalyst.

f This value is determined by dividing the viscosity obtained in the appropriate example by the viscosity of a comparable formulation employing as the catalyst the same nitrogen or phosphorus compound except that it has not been reacted with HBF<sub>4</sub>.

g Composition viscosity exceeded the test method (&gt;200,000 cps).

## Claims

## 1. Use of at least one catalyst (C) resulting from contacting

(1) at least one compound selected from

- (a) an onium compound of the element nitrogen, phosphorus, sulfur or arsenic,
- (b) an amine compound or an acid adduct thereof, with

(2) at least one compound selected from

- (a) an inorganic acid free of boron or a metal salt thereof, said inorganic acid having a weak nucleophilic anion,
- (b) an inorganic acid containing boron or a metal salt thereof, said inorganic acid being represented by the formula  $\text{HBR}_3\text{R}'$  wherein each R is independently hydrogen or an aliphatic, cycloaliphatic or aromatic hydrocarbyl group having from 1 to 12 carbon atoms or a halogen and R' is a hydrocarbonoxy, a hydrocarbonamino, a hydrocarbonphosphino or a halogen atom and
- (c) any combination of components (a) or (b);

whereby components (C-1) and (C-2) are contacted in quantities which satisfy following viscosity requirement: if 181.5 g of a diglycidyl ether of bisphenol A having an epoxy equivalent weight of 181.5 and 114 g of bisphenol A are heated in 73.88 g monomethylether of propylene glycol momoacetate (PMA) under a nitrogen atmosphere between 80°C-100°C until homogeneous and cooled to ambient temperature and 9 mmol of catalyst (C) are added that mixture has a viscosity measured at 25°C of 75% or less than the viscosity of a like composition except that the catalyst consists only of component (C-1) said viscosity being determined after storage for 14 days at 50°C

in a precatalyzed resin formulation further comprising:

- (A) at least one compound containing an average of more than one epoxide group per molecule and
- (B) at least one compound containing an average of more than one aromatic hydroxyl group per molecule other than an alkenylphenol polymer, in a quantity to provide a ratio of 0.05 to 20 aromatic hydroxyl groups per epoxide group and
- (D) a solvent in a quantity of 0.05 to 100 mmol per epoxide equivalent in component (A) to import storage stability to said precatalyzed resin formulation. Wherein storage stability is defined in that said precatalyzed resin formulation is capable of being stored at 50°C for at least 14 days.

## 2. Use of claim 1

**characterized in that**

component (C-1) contains a phosphonium moiety.

## 3. Use of claim 2

**characterized in that**

the catalyst is made by contacting from 1.1 to 1.25 equivalents of component (C-2) per equivalent (C-1).

## 4. Use of claim 1

**characterized in that**

component (C-1) contains an ammonium or amine moiety.

## 5. Use of claim 1

**characterized in that**

component (C-1) contains an imidazolonium or imidazole moiety.

## 6. Use of any of claims 4 or 5

**characterized in that**

the catalyst is made by contacting from 0.85 to 1.12 equivalents of component (C-2) per equivalent (C-1).

## 7. Use of any of claims 1-6



characterized in that

component (C-2) is a boron-containing acid represented by the Formula  $\text{HBR}_3\text{R}'$ .

8. Use of claim 7

characterized in that

each R is a halogen.

9. Use of any of claims 1-6

characterized in that

component (C-2) is fluoroboric acid.

## Patentansprüche

1. Verwendung wenigstens eines Katalysators (C), der resultiert aus dem Inkontaktbringen

(1) wenigstens einer Verbindung, ausgewählt aus

(a) einer Oniumverbindung des Elementes Stickstoff, Phosphor, Schwefel oder Arsen,

(b) einer Aminverbindung oder eines Säureadduktes davon, mit

(2) wenigstens einer Verbindung, ausgewählt aus

(a) einer anorganischen Säure, die kein Bor enthält oder ein Metallsalz davon, wobei die anorganische Säure ein schwach nukleophiles Anion bildet,

(b) einer anorganischen Säure, die Bor enthält, oder ein Metallsalz davon, wobei die anorganische Säure durch die Formel  $\text{HBR}_3\text{R}'$  wiedergegeben ist wobei jedes R unabhängig voneinander Wasserstoff oder eine aliphatische, cycloaliphatische oder aromatische Kohlenwasserstoffgruppe mit 1 bis 12 Kohlenstoffatomen oder ein Halogen ist und R' Hydrocarboxy, Hydrocarbonamino, Hydrocarbonphosphino oder ein Halogenatom ist, und

(c) jeglicher Kombination der Komponenten (a) oder (b),

wobei Komponenten (C-1) und (C-2) in Mengen in Berührung gebracht werden, die folgende Viskositätsbedingung erfüllen:

wenn 181,5 g eines Diglycidylethers von Bisphenol A mit einem Epoxyäquivalentgewicht von 181,5 und 114 g Bisphenol A in 73,88 g Monomethylether von Propylenglykolmonoacetat (PMA) unter einer Stickstoffatmosphäre auf zwischen 80°C und 100°C erwärmt werden, bis sie homogen sind, und dann auf Umgebungstemperatur abgekühlt werden und 9 mmol des Katalysators (C) zugesetzt werden, dann hat die Mischung eine Viskosität gemessen bei 25°C von 75% oder weniger als die Viskosität einer gleichen Zusammensetzung, mit der Ausnahme, daß der Katalysator nur aus der Komponente (C-1) besteht, wobei diese Viskosität nach 14-tägiger Lagerung bei 50°C bestimmt wird,

in einer vorkatalysierten Harzformulierung, die weiterhin enthält:

(A) wenigstens eine Verbindung, die im Mittel mehr als eine Epoxidgruppe pro Molekül enthält, und

(B) wenigstens eine Verbindung, die im Mittel mehr als eine aromatische Hydroxylgruppe pro Molekül enthält die kein Alkenylphenolpolymer ist, in einer Menge, um ein Verhältnis von 0,05 bis 20 aromatische Hydroxylgruppen pro Epoxidgruppe bereitzustellen, und

(D) ein Lösungsmittel

in einer Menge von 0,05 bis 100 mmol pro Epoxidäquivalent in der Komponente (A), um dieser vorkatalysierten Harzformulierung Lagerstabilität zu verleihen, wobei Lagerstabilität so definiert ist, daß diese vorkatalysierte Harzformulierung in der Lage ist, wenigstens 14 Tage lang bei 50°C gelagert zu werden.

2. Verwendung nach Anspruch 1,

dadurch gekennzeichnet,

daß die Komponente (C-1) eine Phosphoniumeinheit enthält.

3. Verwendung nach Anspruch 2,  
**dadurch gekennzeichnet,**  
daß der Katalysator durch Inberührungbringen von 1,1 bis 1,25 Äquivalenten der Komponente (C-2) pro Äquiva-  
lente der Komponente (C-1) hergestellt wird.
4. Verwendung nach Anspruch 1,  
**dadurch gekennzeichnet,**  
daß die Komponente (C-1) eine Ammonium- oder Amineinheit enthält.
5. Verwendung nach Anspruch 1,  
**dadurch gekennzeichnet,**  
daß die Komponente (C-1) eine Imidazolonium- oder Imidazoleinheit enthält.
6. Verwendung nach einem der Ansprüche 4 oder 5,  
**dadurch gekennzeichnet,**  
daß der Katalysator durch Inberührungbringen von 0,85 bis 1,12 Äquivalenten der Komponente (C-2) pro Äqui-  
valente (C-1) hergestellt wird.
7. Verwendung nach einem der Ansprüche 1 bis 6,  
**dadurch gekennzeichnet,**  
daß die Komponente (C-2) eine borhaltige Säure ist, die durch die Formel  $\text{HBR}_3\text{R}'$  wiedergegeben ist.
8. Verwendung nach Anspruch 7,  
**dadurch gekennzeichnet,**  
daß jedes R ein Halogen ist.
9. Verwendung nach einem der Ansprüche 1 bis 6,  
**dadurch gekennzeichnet,**  
daß die Komponente (C-2) Tetrafluorborssäure ist.

## Revendications

1. Utilisation d'au moins un catalyseur (C) qui est le résultat du fait de mettre :

(1) au moins un composé choisi parmi :

- (a) un composé de type onium de l'élément azote, phosphore, soufre ou arsenic,
- (b) un composé de type amine ou un produit d'addition acide de ce dernier,

en contact avec

(2) au moins un composé choisi parmi :

- (a) un acide minéral qui ne contient pas d'atome de bore ou un sel métallique de ce dernier, ledit acide minéral ayant un anion faiblement nucléophile,
- (b) un acide minéral contenant un atome de bore ou un sel métallique de ce dernier, ledit acide minéral étant représenté par la formule  $\text{HBR}_3\text{R}'$  dans laquelle chaque R représente indépendamment un atome d'hydrogène ou un groupe hydrocarboné aliphatique, cycloaliphatique ou aromatique comportant de 1 à 12 atomes de carbone ou un atome d'halogène, et R' représente un groupe hydrocarboné-oxy, hydrocarboné-amino, hydrocarboné-phosphino ou un atome d'halogène et
- (c) toute combinaison des composants (a) ou (b) ;

les composants (C-1) et (C-2) étant mis en contact en des quantités qui satisfont à l'exigence suivante, qui concerne la viscosité : si on chauffe sous une atmosphère d'azote à une température de 80 à 100° C, 181,5 g d'un éther diglycidyle de bisphénol A présentant un poids d'équivalent époxy de 181,5 et 114 g de bisphénol A dans 73,88 g d'un éther monométhyle d'un monoacétate de propylèneglycol (PMA) jusqu'à ce qu'on obtienne un mélange homogène et, on refroidit le tout à température ambiante et on ajoute 9 mmoles de catalyseur (C), de manière à ce que le mélange ait une viscosité mesurée à 25° C, qui représente 75 %

ou moins de la viscosité d'une composition identique à l'exception près que le catalyseur comprend seulement le composant (C-1), ladite viscosité étant déterminée après stockage pendant 14 jours à 50° C ;

dans une formulation de résine précatalysée comprenant en outre :

- (A) au moins un composé comportant une moyenne de plus d'un groupe époxyde par molécule, et
- (B) au moins un composé comportant une moyenne de plus d'un groupe hydroxyle aromatique par molécule autre qu'un polymère d'alcénylphénol, en une quantité qui permette de fournir de 0,05 à 20 groupes hydroxyle aromatiques par groupe époxyde, et
- (D) un solvant ;

en une quantité de 0,05 à 100 mmoles par équivalent époxyde dans le composant (A) pour donner une stabilité lors du stockage à ladite formulation de résine précatalysée, utilisation dans laquelle on définit la stabilité lors du stockage par le fait que ladite formulation de résine précatalysée peut être stockée à 50°C pendant au moins 14 jours.

2. Utilisation conforme à la revendication 1, caractérisée en ce que le composant (C-1) contient une partie de type phosphonium.
3. Utilisation conforme à la revendication 1, caractérisée en ce qu'on prépare le catalyseur en mettant en contact de 1,1 à 1,25 équivalents de composant (C-2) par équivalent de composant (C-1).
4. Utilisation conforme à la revendication 1, caractérisée en ce que le composant (C-1) contient une partie de type amine ou ammonium.
5. Utilisation conforme à la revendication 1, caractérisée en ce que le composant (C-1) contient une partie de type imidazolonium ou imidazole.
6. Utilisation conforme à l'une quelconque des revendications 4 et 5, caractérisée en ce qu'on prépare le catalyseur en mettant en contact de 0,85 à 1,12 équivalents de composant (C-2) par équivalent de composant (C-1).
7. Utilisation conforme à l'une quelconque des revendications 1 à 6, caractérisée en ce que le composant (C-2) est un acide contenant un atome de bore représenté par la formule  $\text{HBR}_3\text{R}'$ .
8. Utilisation conforme à la revendication 7, caractérisée en ce que chaque R représente un atome d'halogène.
9. Utilisation conforme à l'une quelconque des revendications à 6, caractérisée en ce que le composant (C-2) est l'acide fluoborique.